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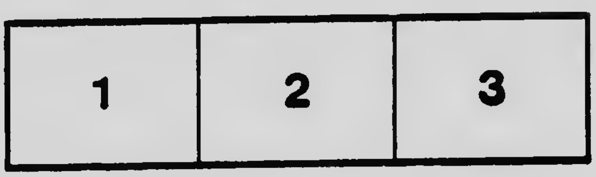

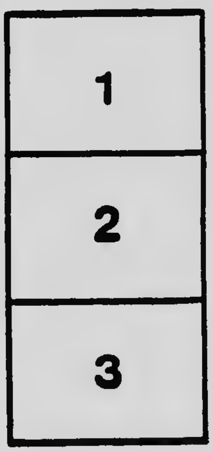

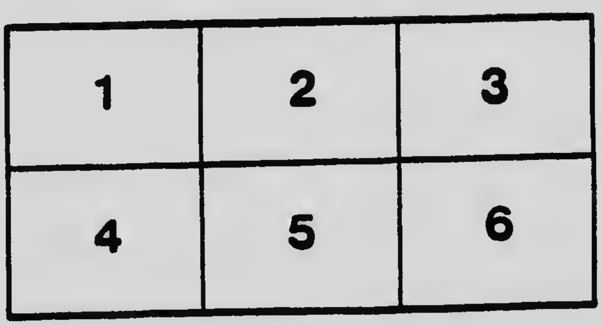

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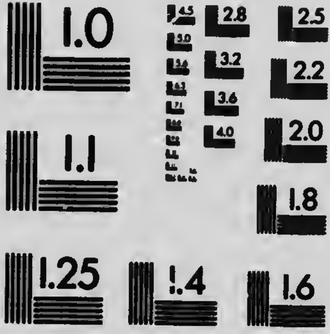

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GEOLOGICAL SURVEY BRANCH
Hon. W. Templeman, Minister; A. P. Low, Deputy Minister;
R. W. Brock, Director.

MEMOIR No. 9-E

BIGHORN COAL BASIN

ALBERTA

BY

G. S. Malloch

OTTAWA
GOVERNMENT PRINTING BUREAU
1911

No. 1130

MESOZOIC

QUATERNARY

Can...
Department...
GEOLOGICA...

Hon W Templeman, Minister...
R.W Brock, ...

LEGEND

QUATERNARY — PLEISTOCENE AND RECENT

Q	Glacial and river drift
K6	Brazeau sandstones, shales and conglomerates
K5	W..piabi shales
K4	Bighorn sandstones and conglomerates
K3	Blackstone shales
K2	Dakota sandstones and shales
K1	Kootanie formation (coal-bearing) (Siliceous and shaly sandstones, black shales, coal, and conglomerates)

MESOZOIC — UPPER CRETACEOUS (K3–K6) — LOWER CRETACEOUS (K1–K2)

Bird's-ey...

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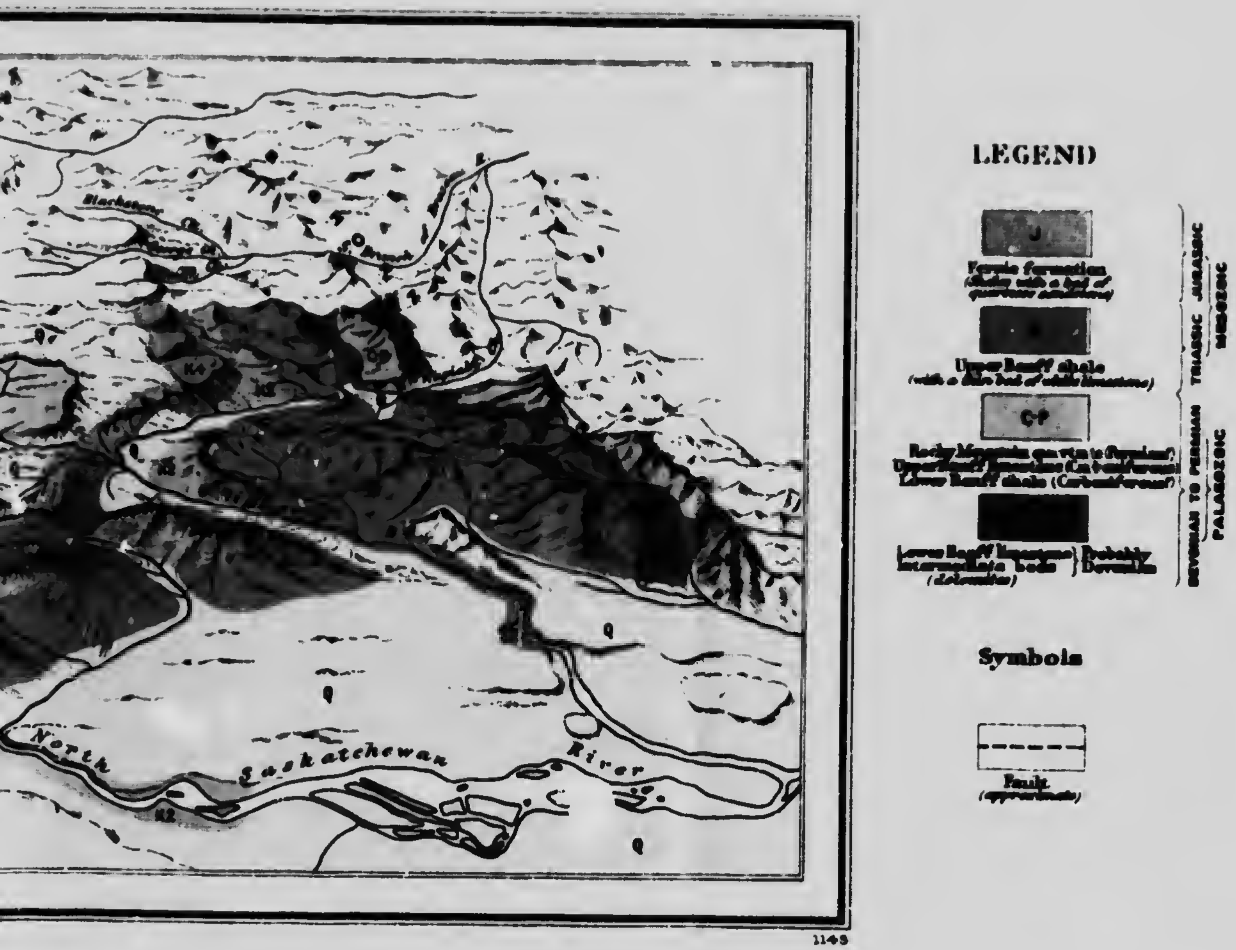
Canada
Department of Mines
GEOLOGICAL SURVEY

...n, Minister; A. P. Low, Deputy Minister;
R. W. Brock, Director

1909



...rd's-eye view
...outhern portion of the
...RN COAL BASIN
...OUNTAINS AND FOOTHILLS
ALBERTA

To accompany Memoir No. 9

CANADA
DEPARTMENT OF MINES
GEOLOGICAL SURVEY BRANCH
HON. W. TEMPLEMAN, MINISTER; A. P. LOW, DEPUTY MINISTER;
R. W. BROCK, DIRECTOR.

MEMOIR No. 9-E

BIGHORN COAL BASIN

ALBERTA

BY

G. S. Malloch

OTTAWA
GOVERNMENT PRINTING BUREAU
1911

1125½—1 No. 1130

To R. W. Brock, Esq.,

Director Geological Survey,

Department of Mines,

Ottawa.

Sir,—I beg to submit the following Memoir on the Bighorn Coal Basin, Alberta.

I have the honour to be,

Sir,

Your obedient servant,

(Signed) **G. S. Malloch.**

Ottawa, May 9, 1910.

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General Geology—*Con.*

ILLUSTRATIONS.

Map.

BIGHORN COAL BASIN, ALBERTA.

BY

G. S. MALLOCH.

INTRODUCTORY.

General Statement and Acknowledgments.

The Bighorn coal basin, situated in western Alberta, is named from the Bighorn range, an outlier of the Rocky mountains, 9 miles east of the first range, and extending from the North Saskatchewan to the Brazeau river. The first discovery of coal in the basin between this range and the mountains was made by Mr. D. B. Dowling, in 1906. Analyses of his samples proved that the coal was well adapted for use in locomotives, and inasmuch as at that time, no occurrence of a satisfactory fuel was known nearer to the routes of the Grand Trunk Pacific, and Canadian Northern railways, the discovery attracted much attention when made public soon after Mr. Dowling's return. Two companies purchased large holdings in the basin, shortly afterwards, and its importance as a coal field was fully proved in 1907, when Mr. Dowling discovered that the coal-bearing formation contained at least nine workable seams, with an aggregate thickness of 66 feet. The next summer the German Development Company sent Mr. James McEvoy to make a thorough examination of their properties. During the same season the writer, in accordance with the instructions of the Director of the Geological Survey, made a photo-topographic survey of the basin and a study of its geological structure. Mr. McEvoy, who was a member of the Geological Survey for a number of years, has furnished sections of the Coal Measures, at two widely separated points, with thicknesses of the various seams, and analyses of carefully averaged samples from the more important ones. He also made paced compass traverses of the most important trails, and these have proved of great service in filling in topographic details of the map accompanying this report. The writer's thanks are also due to him for suggestions made in the field, and for the interest he has shown in the map during its compilation.

Use has also been made of plans of the German Development Company's claims, which were furnished by Mr. T. D. Green, D.L.S., and of other information obtained from officers of the Topographical Surveys Branch of the Department of the Interior. The writer's assistants, Messrs. S. J. Schofield, and J. W. Shipley, rendered very efficient service in the prosecution of the survey. The packer employed, E. J. Ballard, showed great zeal in searching for fossils, and found many of the specimens, a list of which is given below. For their determination the writer is indebted to Professor Charles Schuchert of Yale University, and to Dr. T. W. Stanton, and Dr. F. H. Knowlton of the United States Geological Survey.

Photo-Topographic Survey.

The photo-topographic survey was controlled by a chain of triangles developed from a base a mile and a quarter in length. The triangles were tied to the quarter section post between section 7, township 43, range XVIII, and section 12, township 43, range XIX, and the latitude and longitude lines on the map are based on the theoretical position of this post. In addition to the main triangulation stations a large number of camera stations were occupied, and their positions fixed either by sights to and from triangulation stations, or by the three point problem checked by sights to additional stations. Numerical solutions were made of the triangles formed by these sights, and except for four unimportant stations, checks of the lengths of sides showed discrepancies of less than 20 feet. Twenty-five dozen photographs were taken in all, and by means of them the positions of over three thousand points were fixed to control the topography. Angles of elevation or depression were read at each sight with the transits to secure vertical control, but since a datum elevation was not available, and time was pressing, the relief on the map is represented by hachures and not contours.

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General view of the Bighorn basin, from the first range of the Rocky

1125½—p. 10.

f the Rocky Mountains, showing entire length of Bighorn range.

Area and Location.

The area mapped is bounded on the northeast and southwest respectively by the Bighorn range, and the first range proper of the Rocky mountains. These ranges form the geological as well as the topographic boundaries of the basin; and though the coal-bearing strata extend beyond the Saskatchewan and Brazeau rivers, the term basin is no longer applicable there, owing to the dying down of the Bighorn range, which does not form a well marked topographic feature except between these rivers. On the south, the valley of the Saskatchewan is mapped, and the slopes of the first range and the foothills east of it. To the north of the basin, the valley of the Brazeau is very broad owing to the confluence of three large tributaries, but because of lack of sufficient time it was found impossible to survey more than a portion of it.

The length of the area mapped southeast to northwest is about 36 miles, and its average width about 9 miles. The area is, therefore, about 320 square miles. The basin is situated, roughly, 85 miles northwest of Banff, 140 miles west-southwest of Edmonton, and 70 miles south of the surveyed routes of the Grand Trunk Pacific and Canadian Northern railways.

Means of Communication.

At present the basin can be reached by means of pack trails only. The shortest of these leaves the main line of the Canadian Pacific railway at Laggan, ascends the Pipestone to the high pass of that name, descends the Siffleur to the Saskatchewan, and follows it for about 18 miles to the basin. This trail cannot be used in the winter, spring, or early summer, owing to the depth of snow which accumulates in the pass. Another trail leaves Banff and follows the Cascade trough, crossing Panther creek, Red Deer, and Clearwater rivers, and descends to the Saskatchewan by Rabbit creek, which enters it about 2 miles below the mouth of the Siffleur. The four summits on this trail are from 1,000 to 2,000 feet lower than the Pipestone pass, so that it can be used much earlier in the summer. Another trail, much used by the Stoney Indians, leaves their reserve at Morley, and traverses the foothills to the Red Deer river, by which it enters the mountains. It then crosses to the Clearwater by a low divide situated in the longitudinal valley between the first and second ranges, and ascends the river valley until it unites with the trail just mentioned. The basin may also be reached either from Morley or Innisfail without entering the mountains at all, but a number of bad muskegs have to be crossed.

Previous Work

The only previous examinations of the basin were made by Mr. D. B. Dowling, in 1906 and 1907. Reference has already been made to them, and the accounts of his explorations will be found in the Summary Reports for those years.[1] A number of other reports, while not dealing with the basin, describe geological formations recognized in it, and types of mountain structures found there. In 1885, Dr. G. M. Dawson published a Preliminary Report on the Physical and Geological Features of that Portion of the Rocky Mountains between Latitudes 49° and 51° 30′.[2] This report gives a good general description of the portion of the Rockies with which it deals. In 1886, Mr. R. G. McConnell measured a section of the strata exposed along the main line of the Canadian Pacific railway from the first range of the mountains to the Columbia valley, which separates the Rockies from the Selkirks.[3] In 1898, Mr. James McEvoy crossed the Rockies by the Yellowhead pass, 140 miles north of the Canadian Pacific railway, and found that the stratigraphic section there corresponds closely with that described by Mr. McConnell. On his return journey he descended a branch of the Brazeau river, and passed within a few miles of the northwest corner of the area mapped.[4] In 1900, Mr. McEvoy made a survey of the Crowsnest coal field and measured the Kootanic formation in which the coal seams are found.[5] This formation occurs at intervals in the first, second, and third longitudinal valleys of the Rockies, and its outcrops have now been examined for almost the entire distance from the boundary to the route of the Grand Trunk Pacific, nearly 300

[1] G.S.C. Summary Report for 1906, pp. 72-73, and for 1907, pp. 32-34.
[2] G.S.C. Annual Report, Vol. I, 1885, part B.
[3] G.S.C. Annual Report, Vol. II, 1886, part D
[4] G.S.C. Annual Report, Vol. XI, 1898, part D.
[5] G.S.C. Annual Report, Vol. XIII, 1900, part A, pp. 85-95

miles north of it. The greater part of this work has been done by Mr. D. B. Dowling, accounts of whose exploration may be found in the Summary Reports from 1903 to 1909.

With few exceptions, the Kootanie is the highest formation which has escaped the very rapid action of erosion at the higher elevations within the mountains; but, outside in the foothill region, the Kootanie is overlaid by seven newer formations, which, with it, give an enormously thick section laid down in Cretaceous time. This section was measured by Mr. D. D. Cairnes, who worked in the foothill region, south of the Canadian Pacific railway, in 1905, and found the Kootanie formation outcropping about Moose mountain and Forget-menot range, which are outliers at some distance in front of the mountains proper.[1] The Bighorn basin lies with the Bighorn range—another outlier—and the four formations which there overlie the Kootanie may be correlated on lithological grounds with corresponding formations in Mr. Cairnes' section.

Besides his Summary Reports, in 1907 Mr. Dowling published a report on the Cascade Coal Basin,[2] and in 1909 a general report on the Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia.[3] In the latter he gives an estimate of the amount of coal which might be produced in the Bighorn basin under present economic conditions, which will probably limit the productive area to a strip a mile wide along the eastern edge of the basin. His estimate is 1,400,000,000 long tons.

GENERAL CHARACTER OF THE DISTRICT.

Topography.

GENERAL ACCOUNT.

Regional.—In character the topography of the basin is intermediate between that of the eastern ranges of the Rocky mountains and the foothills east of them. For the greater part of the distance from the International Boundary to the Athabaska river there is a sharp line of division between the two types. To the east the foothills

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[1] G.S.C. Report on the Moose Mountain district of Southern Alberta, by D. D. Cairnes. No. 968.

[2] G.S.C. No. 919.

[3] G.S.C. No. 1,035.

form a succession of long ridges with even crest lines, and without noticeable differences in elevation, while to the west, the mountains are much higher and exhibit serrate crest lines and great irregularity in height. Seen from Calgary, situated 50 miles east of them, the mountains extend in a long line of peaks and appear to rise as abruptly from the foothill region as from a plain.

At certain intervals, however, outlying ranges occur in front of the general line of the mountains, and at various distances from it. In height, these outliers are not greatly inferior to the mountain ranges; but, unlike them, they extend for short distances only, and near their extremities they are so reduced in height that they pass almost imperceptibly into ridges of no greater elevation than the other foothills.

Both the mountains and the foothills are crossed by the deep transverse valleys of the rivers draining the region. Some of the rivers, like the Bow, follow longitudinal valleys for some distance, but the majority break almost directly across the ranges, and receive only small tributaries from the longitudinal valleys. The general direction of the ranges of the mountains and ridges of the foothills is southeast and northwest.

Local.—The distance between the Bighorn and first range—about 9 miles—is much greater than is usual between the ranges of the mountains, and the intervening basin bears a strong resemblance to the foothill country. It is traversed by three fairly well defined ridges running parallel with the bordering ranges. These ridges differ from foothills only in their slightly greater height and more irregular outlines. The transverse valleys of the Saskatchewan and Brazeau are broad and deep, and their tributaries, with three other streams which break through the Bighorn range, so dissect the area that its basin-like form only becomes apparent when a mountain is climbed, and its general elevation can be compared with that of the bordering ranges. The general elevation of the basin is between 2,000 and 3,000 feet below the ranges, and about 2,000 feet above the deep valley of the Saskatchewan.

DETAILED ACCOUNT.

Drainage.—The valleys of the Saskatchewan and Brazeau run across the ends of the basin. They are broad and deep, and like the

PLATE III.

Central part of Bighorn range, showing gap of Blackstone creek.

other transverse valleys in the mountains and foothills are characteristically U shaped. The valleys increase greatly in width after their debouchures from the mountains to the west; but the side walls, while not precipitous, as they are in the gaps through the ranges, have remarkably steep slopes.

The Saskatchewan receives three tributaries from the basin, but the two farthest west are small and unimportant. Bighorn river, the third, is a stream of considerable size. Two branches rise west of the first range of mountains and break through it in two gaps, 7 and 10 miles from the Saskatchewan. These branches unite a short distance in front of the range and flow southeast across the basin, reaching the Saskatchewan near its eastern edge. The valley of the Bighorn resembles the typical transverse valleys in its upper portion, but lower down it becomes narrower, and ends in a gorge nearly 3 miles long, into which the stream plunges in two vertical falls, the first of which is 55 feet high, and the other 30 feet. From the mouth of this gorge to the Saskatchewan, the Bighorn flows over an extensive fan, formed from the gravel and boulders it has dropped because of the low gradient of the floor of the broad transverse valley.

The only important tributary draining into the Brazeau is Opabin creek, which is less than half the size of Bighorn. This creek heads in a deep cirque in the first range of the mountains, and has a fall 35 feet high a short distance from them. Below, it flows between high banks of glacial till without exposures of bed-rock.

The remainder of the basin is drained by the three streams already mentioned, which break through the Bighorn range in narrow gaps, situated 10, 21, and 27 miles from the Saskatchewan. They have been named Wapiabi, Blackstone, and Chungo creeks, respectively. Branches of the first two head in cirques in the first range, but the last is considerably smaller, and extends back only to the second of the three longitudinal ridges traversing the basin. As far as can be made out from photographs from the Bighorn range, these three streams unite before reaching the Brazeau, into which they seem to flow.

Relief.—The Bighorn range, though only an outlier, reaches an elevation not far short of 8,700 feet, or nearly 4,700 feet above the Saskatchewan valley. This height, and its length of over 30 miles, make it the most important of the outliers which have been described along the edge of the Canadian Rockies. Near the Saskatchewan and Brazeau the height of the Bighorn range decreases rapidly, and beyond them it is represented by ridges no higher than the rest of the foothills.

In its general form the range differs little from the eastern ranges of the mountains. Like them it presents a precipitous face to the northeast, but to the southwest the slope is usually at an angle between 20 and 40 degrees. The crest line is serrate throughout, and cirques have been developed on both sides, cutting the slopes into spurs and re-entrants. The cirques developed on the northeast face are usually deeper, and three of them extend entirely through the range, and are continued as semi-circular depressions behind it.

As has been stated, the basin is traversed by three longitudinal ridges approximately parallel to the bordering ranges. The first of these is only a short distance behind the Bighorn range, but is separated from it by a depression which is never less than 200 feet deep. This ridge bounds the depressions inside the Bighorn range, and, in some cases, it reaches an elevation of 7,500 feet. The outline of the ridge is very irregular, however, and the strata composing it have been much dissected by cirques and stream gullies. Wapiabi, Blackstone, and Chungo creeks divide into numerous tributaries inside the Bighorn range, and then cut through the ridge, often obliquely to its general direction. As a general rule, the ridge reaches its greatest elevation on its western side, but the spurs of the ridge often rise to subordinate summits, and many hills are wholly detached from other portions of the ridge by the valleys of the streams crossing it diagonally. Immediately north of the Saskatchewan, the ridge is cut almost in half by the valley of Bighorn river, and its total width is much increased owing to an irregularity of the geological structure in this locality.

The second longitudinal ridge is much more regular than the first, and, except for the gaps of the larger streams, and a few notch-like depressions cut by smaller ones, it is continuous from the Brazeau valley to that of the Bighorn. The general trend of this ridge is not quite parallel to the Bighorn range, from which it gradually recedes towards the southwest. However, it is never far from the centre of the basin.

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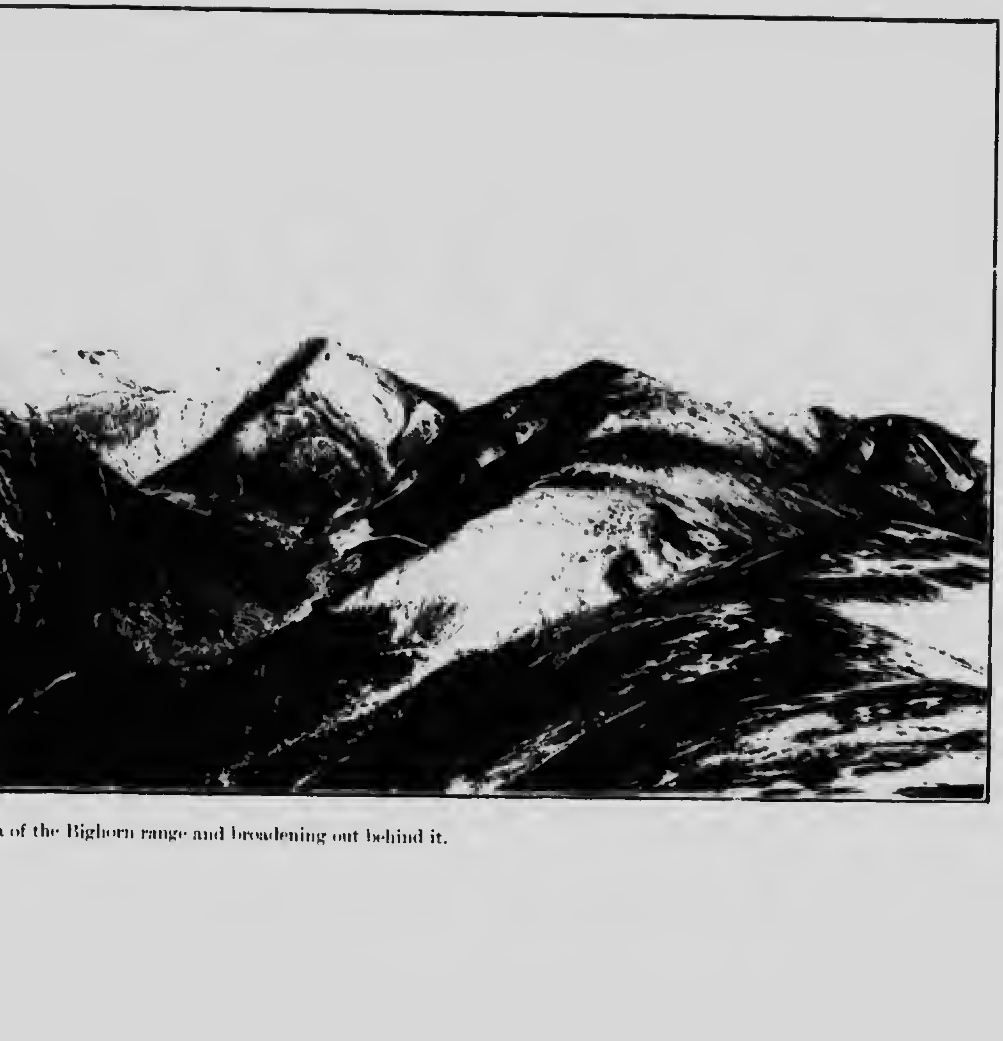
Partial view of the northern cirque cutting through the strata of the Big

Plate IV.



n of the Bighorn range and broadening out behind it.

Except for a rather wide gap occupied by Blackstone creek the third ridge is continuous from the Brazeau valley to the main branch of George creek, and it is represented farther south by three detached hills situated between smaller branches of this creek. Southward from the third of these hills the ridge is absent for over 6 miles, but it begins again south of Wapiabi creek and extends to the Bighorn valley. The higher portions of this ridge exhibit some broad scallop-like indentations, but otherwise there are few minor irregularities in its outline.

In the triangular area, bounded by the first range of the mountains and the Bighorn and Saskatchewan valleys, the distribution of the hills is much more irregular than in the rest of the basin, and they do not readily admit of classification into three ridges. A line of fairly high hills borders the Saskatchewan valley between the mountains and Bighorn river, and is broken only by the valleys of the two small tributaries already mentioned. The eastern of these tributaries is the larger, and after breaking through the flanking hills it bends to the west, and heads in cirques developed on the face of the first range of the mountains. North of this stream two low ridges extend to the Bighorn valley, and between them is a high flat topped hill, with a gentle slope down to this valley. Some other minor elevations occur in this area, and there is a semi-detached hill between the two forks of Bighorn river.

The first range of the Rocky mountains is higher and more rugged than the Bighorn range, and its eastern face is cut into a succession of protruding ridges and shoulders by cirques developed at irregular intervals. Many of these cirques are quite unsymmetrical, exhibiting curved and branching axes, and smaller cirques have often been developed in the walls of larger ones, so that the spurs have an irregularity which may almost be described as fantastic. South of the Saskatchewan the range divides into two, the farthest east of which has been eroded away for 4 miles, and as its continuation beyond is slightly in front of the general line of the range it might be taken for the end of another outlying range. The geological structure shows, however, that this is not the case.

North of the Saskatchewan the general line of the range shows deep embayments from two outstanding peaks, situated 12 and 24 miles from the river. It is in front of these peaks that the thi longitudinal ridge of the basin reaches its greatest elevation

In addition to the transverse valleys of the rivers and strea mentioned there are three well marked longitudinal depressions. T first of these lies between the Bighorn range and the first of t ridges, and is very narrow. Small tributaries on the transver streams drain this depression, and the three cirques piercing the Bi horn range are continued in the same general line as circular hollov The second depression between the first and second ridge is mu wider and flatter, though it is well drained by tributary strean The third, between the second ridge and the third—or between t second and the mountains where the latter is absent—is still wide and many muskegs occur along its eastern side. On the weste side the rock floor is buried under accumulations of glacial dri through which deep trenches have been cut by streams draining fro the cirques under the mountains. South of the Brazeau and nor of the Bighorn, minor depressions occur between the third ridge a the mountains. An anomalous valley extends transversely fro near the junction of the two branches of Bighorn river to the gap Wapiabi creek. This valley is broad and flat, and contains a la more than half a mile long, which is situated only a short distan from the Wapiabi, but which apparently discharges into the Bighor

Climate and Agriculture.—The climate of the basin does n differ much from that of Morley and Banff, on the main line of t Canadian Pacific railway. The rainfall varies somewhat from ye to year, but is always sufficient for the growth of grass wherov openings occur in the woods. Summer frosts are frequent, exce at the low level of the Saskatchewan valley, where turnips have bee grown successfully. Here the growth of grasses and pea vines reach the knee, and is so thick that tracks of horses made fully a mon before could be followed. The frequency with which this valley visited by Chinook winds prevents the accumulation of snow i winter, and it has long been a favourite spot with the Indians f wintering their horses.

Fauna and Flora.—Rocky Mountain sheep, and both black an white tailed deer, are quite plentiful near the Brazeau, but are som what scarce in the vicinity of the Saskatchewan—a favourite haur of the Indians. Lynx, coyotes, rabbits, martin, weasels, porcupin

PLATE V.

Looking west across the basin, showing first range of the Rocky mountains.

11254 p. 18.

squirrels, and chipmunks were either seen or their presence proved by their tracks in the snow. Tracks of a bull moose were also seen, but he evidently returned to the foothills after being in the basin less than a day. The only fish in the streams are silver and bull trout. Some of the latter, weighing 15 pounds, were caught in Blackstone creek by members of Mr. McEvoy's party.

Only seven varieties of trees were seen in the basin—spruce and Banksian pine being much the commonest. The pine flourishes where the soil is sandy and the drainage good, while spruce requires more moisture. One grove of spruce, probably 10 to 12 inches in diameter and 75 feet high, was seen near the mouth of Bighorn river, but the greater part of the Saskatchewan valley and the surrounding hills has been burnt over at a comparatively recent date. There has been much less fire farther north, and the valley of the Brazeau has escaped altogether. Balsam usually grows with the spruce, while aspen poplar and cottonwood are found at lower levels, especially in old brules. A few Douglas fir occur on the gravel banks which line the Saskatchewan.

GENERAL GEOLOGY.

General Statement.

Regional.—With a few minor exceptions, the rocks of the Rocky mountains are of sedimentary origin, and as far as is known they were laid down without unconformity, from lower Cambrian to Cretaceous time. This series of strata is traversed by a succession of enormous thrust faults to which the different ranges owe their elevation. On the eastern side of the mountains the ranges are the result of compression, relieved by thrusting thick blocks of strata upward and northeastward until the Palaeozoic strata at their base have over-ridden younger Mesozoic strata east of them. In one case, described by Mr. McConnell, Cambrian strata override Benton for a distance of nearly 2 miles.[1] With some exceptions, the fault planes to the west have steeper dips than those to the east, and some of them differ but little in angle from the dip of the beds. Disturbances in the foothills affect only the younger beds. These are of

[1] G.S.C. Annual Report, 1886, Part D., pp. 33-34.

Cretaceous age, and consist of a succession of sandstone beds separated by great thicknesses of soft shales. Their composition renders them more likely to crumple than to fault sharply under pressure, and consequently the faults which occur usually have small throws, and seldom reveal themselves in the topography as they commonly do in the mountains.

In the longitudinal valleys within the Rocky mountains the coal-bearing Kootanie, or in a few cases the succeeding Dakota, is the youngest formation represented, and these are exposed only where the distance between the fault blocks is exceptionally wide.

In the foothills, on the other hand, the Kootanie is usually buried under from three to five younger formations, and until 1905[1] it was not known that it reached the surface at any point. In that year, however, Mr. D. D. Cairnes discovered the Kootanie in the vicinity of Moose mountain and Forgetmenot range—two outliers south of the main line of the Canadian Pacific railway. Mr. Cairnes named and described ten formations occurring between the mountains and the boundary of the belt of disturbed strata comprising the foothills. This belt is about 25 miles in width.

Local.—All the formations in Mr. Cairnes' section, except the Bearpaw and Edmonton, are probably represented in the Bighorn basin, and the Palaeozoic limestones which he has grouped together could be divided into five formations, as Mr. Dowling has done in his report on the Cascade Coal basin. On the map, however, the writer has made only one line of division between the Palaeozoic strata, putting the Rocky Mountain quartzites, the Upper Banff limestone, and the Lower Banff shale in the Upper and the Lower Banff limestone, and the Intermediate beds in the lower group.

The strata in the basin form a syncline, whose eastern limb constitutes the fault block known as the Bighorn range. The western limb is overturned, and is overridden to an unequal extent along the western edge of the basin by the strata of the first range of the Rocky mountains. This is due, partly to a convergence between the axis of the syncline and the fault plane, and partly to the irregular outline of the range, some parts of which have been eroded back farther than others.

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[1] G.S.C. No. 968, Moose Mountain District of Southern Alberta, by D. D. Cairnes.

PLATE VI.

View of hollow behind second longitudinal ridge.

Table of Formations.

Quaternary.

1. River drift.
2. Glacial drift.

Upper Cretaceous.

3. Brazeau sandstones, conglomerates, and shales.
4. Wapiabi shales.
5. Bighorn sandstones, conglomerates, and intercalated shales.
6. Blackstone shales.
7. Dakota sandstones and shales.

Lower Cretaceous.

8. Kootanie Coal Measures, consisting of a succession of sandstones and black shales with coal seams and some beds of conglomerate.

Jurassic.

9. Fernie shales with a band of quartzose sandstone.

Triassic.

10. Upper Banff shales with a thin band of white limestone.

Permian ?

11. Rocky Mountain quartzites.

Carboniferous.

12. Upper Banff limestones.

Carboniferous ?

13. Lower Banff shales.

Devonian.

14. Lower Banff limestones.
15. Intermediate beds

Detailed Section.

Detailed sections were measured with chain and clinometer compass from the uppermost beds of the Brazeau formation which have escaped erosion, down to the top of the Upper Banff limestone. The portion of the section from the Brazeau formation to the base of the Dakota was measured on the more southerly of the two main branches of Wapiabi creek. A break occurs in the section through the Wapiabi formation, so that its thickness is probably much above the figure given. The Kootanie formation was measured on Chungo creek; and the Fernie, Upper Banff shale, and Rocky Mountain quartzite where they outcrop on the hills immediately north of Blackstone creek. The total section in descending order is as follows:—

BRAZEAU FORMATION.

	Feet.
1. Greenish grey sandstones with chert pebbles scattered through them in irregular lenses. Grey pebbles predominate..	144
2. Black and brown shale..	209
3. Greenish grey sandstone..	6
4. Black and brown shale..	108
5. Greenish grey sandstone with chert pebbles..	10
6. Brown and black shale..	65
7. Greenish grey sandstone with chert pebbles..	31
8. Brown and black shale..	116
9. Shaly sandstone weathering to a deep brown colour.. ..	57
10. Greenish grey sandstones with chert pebbles..	18
11. Brown and black shales with thin beds of sandstone which weather brown, but are grey on fracture.. ..	87
12. Brown and black shale..	69
13. Grey sandstone with a few pebbles and plant impressions.	15
14. Black and brown shales with bands of shaly sandstone ..	190
15. Sandstone with a few chert pebbles..	11
16. Heavy bed of greenish grey sandstone with chert pebbles; blue pebbles are common but grey ones predominate..	22
17. Black and brown shale with bands of shaly sandstone..	58
18. Coarse grey sandstone with a few chert pebbles..	19
19. Brown shale with thin bands of shaly sandstone..	120
20. Greenish grey sandstone which crumbles easily..	35
21. Brown shale with a thin bed of sandstone..	51
22. Brown and black shales with bands of sandstone and concretions..	28
23. Concealed..	19
24. Conglomerate of small chert pebbles, dark blue, green, white, grey, and red in colour. The first greatly predominate..	10
25. Concealed..	25
26. Similar conglomerate with some pebbles as large as hens' eggs..	8
27. Siliceous sandstone with impressions of plants	2
28. Similar conglomerate..	2
29. Grey siliceous sandstone weathering to reddish tint.. ..	23
30. Concealed..	100
31. Brown sandstone, rather shaly, crumbles easily..	22
Total..	1,680

WAPIABI FORMATION.

	Feet.
1. Brown shale, arenaceous in places, partly concealed.. ..	142
Break in section.	
2. Dark grey, somewhat arenaceous shale, with concretions of clay ironstone and numerous ammonites and other fossils..	473
3. Similar shales with concretions but apparently no fossils.	700
Total measured..	1,315

BIGHORN FORMATION.

1. Hard grey siliceous, which weathers red and is capped by 1 foot of conglomerate, and contains some obscure fossils..	79
2. Brown shale..	19
3. Siliceous sandstone, capped by 8 inches of conglomerate containing blue, white, pink, and green chert pebbles. The sandstone becomes fine-grained below..	37
4. Similar siliceous sandstone, capped by 6 inches of conglomerate. Surface of sandstone has a blue cast..	6
5. Coarse-grained sandstone with a shaly matrix. Contains two bands of grey shale..	16
6. Dark grey shale, showing transition from sandstone above by thin ribs of sandstone. Contains concretions and Inocerami..	67
7. Shaly sandstone..	4
8. Dark grey shale..	12
9. Hard grey siliceous sandstone weathering red..	37
10. Black shale..	12
11. Shaly sandstone..	7
12. Black shale..	67
13. Siliceous grey sandstone..	11
14. Shaly sandstone, passing into arenaceous shale below.. ..	16
Total..	390

BLACKSTONE FORMATION.

1. Calcareous shales dark grey in colour, with bands of concretions but apparently no fossils..	1,050

DAKOTA FORMATION.

1. Sandstone, shaly in places and greenish in colour..	17
2. Grey shale..	26
3. Similar sandstone..	11
4. Grey shale..	15
5. Similar sandstone..	34
6. Grey shale..	54
7. Similar sandstone..	43
8. Grey shale..	241
9. Similar sandstone..	10
10. Grey shale..	37
11. Similar sandstone..	29
12. Grey shale..	28
13. Similar sandstone..	20
14. Grey shale..	32
15. Grey shaly sandstone..	48
16. Grey shale..	121
17. Sandstone..	33
18. Shale..	145

	Feet.
19. Sandstone..	23
20. Shale..	34
21. Sandstone..	2
22. Shale..	3
23. Sandstone..	8
24. Shale..	85
25. Sandstone..	15
26. Brown shale..	68
27. Sandstone..	4
28. Black shale..	4
29. Sandstone..	10
30. Black shale..	58
31. Sandstone..	3
32. Shale..	13
33. Sandstone..	12
34. Shale..	59
35. Sandstone..	38
36. Shale..	39
37. Sandstone..	3
38. Brown shale..	196
39. Sandstone weathering brown, but grey on fracture..	60
40. Brown shale, with purplish cast..	12
41. White sandstone, with greenish cast..	10
42. Shale similar to No. 40..	86
43. White sandstone, with greenish cast..	10
Total..	1,739

KOOTANIE FORMATION.

1. Black and grey shale..	131
2. Coal..	2·4
3. Black shale..	2·9
4. Coal..	4·7
5. Black shale, with ribbons of coal..	161
6. Coal..	3·9
7. Sandstone..	2·5
8. Coal..	2·4
9. Black shale, and shaly sandstone..	127
10. Coal..	4·5
11. Black and brown shale..	131
12. Sandstone shaly below, heavy bedded above..	54
13. Black and brown shales..	53
14. Coarse sandstone, weathers yellow..	37
15. Black and brown shale..	56
16. Heavy beds of sandstone..	22
17. Coal with 0·6 foot of shale ⅓ way up..	**6·6**
18. Black shale, with a coal seam not dug out..	5
19. Siliceous sandstone..	8
20. Black shale, with at least one coal seam which was not dug out..	179
21. Coarse grey sandstone..	7
22. Sandstones separated by black shales..	56
23. Black shale..	33
24. Coal..	2
25. Sandstones separated by black shale..	74
26. Black shale, with calcareous band containing shells of nuculoids and gastropods..	154
27. Grey sandstone..	35
28. Black shale and shaly sandstone..	133
29. Siliceous sandstone..	10
30. Black shale..	57
31. Massive grey sandstone..	59

	Feet.
32. Concealed, probably black shale..	85
33. Shaly sandstone..	6
34. Sandstones and black shales (crumpled) approximately.	100
35. Heavy bed of grey sandstone..	48
36. Black shale..	12
37. Heavy bed of grey sandstone..	32
38. Beds of sandstone separated by black shales and ribbons of coal..	123
39. Black shale..	54
40. Siliceous sandstone..	6
41. Conglomerate, pebbles of chert, generally dark blue in colour, but sometimes light green, grey, and pink.	12
42. Shaly sandstones, separated by black shales..	38
43. Siliceous sandstone..	3
44. Black shales and shaly sandstones..	103
45. Coarse grey sandstone..	14
46. Black shales and shaly sandstones.	97
47. Siliceous sandstone..	2
48. Black shales and shaly sandstones (these show evidence of contemporaneous erosion)..	110
49. Succession of black shales and shaly sandstones, with 3 ribbons of coal, 0·6, 1·4, and 0·3 feet thick..	76
50. Siliceous sandstone, weathering to bluish cast..	3
51. Black shale and shaly sandstones, with 2 ribbons of coal..	126
52. Sandstones with 2 ribbons of coal..	6
53. Siliceous sandstone..	8
54. Black shales, with 3 ribbons of coal, all under 1 foot in thickness..	109
55. Sandstone, showing ripple marks and impressions of rain drops..	21
56. Siliceous sandstones, separated by beds of black shale..	68
57. Grey siliceous sandstone..	50
58. Black shale..	42
59. Thin-bedded sandstones, with fossil plants..	40
60. Black shale, with one thin band of sandstone..	47
61. Siliceous sandstone which weathers red..	37
62. Concealed, probably black shale..	158
63. Heavy bed of sandstone..	30
64. Concealed, probably black shale..	33
65. Sandstone, grey on fracture, but weathering to brown colour..	9
66. Black shale..	74
67. Grey sandstones, separated by beds of black shale.. ..	173
68. Grey sandstones..	5
69. Black shale, with ribbons of sandstone..	75
70. Heavy bed of sandstone..	10
Total..	3,658·9

FERNIE SHALES.

1. Black shale, with thin bands of sandstone..	91
2. Bed of brown sandstone, bluish grey on fracture	1·5
3. Black shale, with ribbons of sandstone	98
4. Black shale..	112
5. Band of ironstone concretions..	3
6. Soft black shale..	113
7. Black limestone, with numerous belemites..	2
8. Quartzose sandstone, with some rounded pieces of black shale in the lowest bed..	71
9. Soft black shale, pyritiferous in places..	101

	Feet.
10. Band of grey calcareous sandstone, with impressions of ammonites and other fossils..	10
11. Black shale, hard and siliceous in places..	76
12. Sandstone, with calcareous cement, black on fracture but weathering white..	14
Total..	722·5

UPPER BANFF SHALES.

1. Calcareous and arenaceous shales in heavy beds, dark grey on fracture, but weathering to reddish brown..	45
2. Similar shales in thin beds..	13
3. Thick beds, weathering to a drab colour, with cherty concretions..	49
4. Similar beds without concretions..	4
5. Hard fine-grained sandstone..	11
6. Calcareous fine-grained sandstone..	22
7. Band of cream coloured limestone..	25
8. Calcareous and arenaceous shales in heavy beds, dark grey on fracture, but weathering to reddish brown..	30
9. Similar shales in thin beds..	20
10. Similar shales, again in heavy beds..	74
Total..	293

ROCKY MOUNTAIN QUARTZITES.

1. Pure quartzite of opal-like cast..	17
2. Calcareous quartzite, weathering white, with bands of yellow siliceous shale..	30
3. Calcareous quartzite, weathering white..	8
4. Calcareous quartzite, with bands of shale similar to No. 2..	19
Total..	74
Grand total of nine formations..	10982·4

Description of Formations.

INTERMEDIATE BEDS AND LOWER BANFF LIMESTONES.

Distribution.—The Intermediate beds, and Lower Banff limestones, have been grouped under one colour on the map, since no very definite line has been drawn between them. They are both of Devonian age. These formations constitute all the mapped portion of the first range of the Rocky mountains. The Lower Banff limestone occurs in thick beds capping most of the peaks in this range, and the higher ones in the Bighorn. The Intermediate beds outcrop on the eastern faces of the ranges.

Lithological Characters.—The Intermediate beds consist of a succession of dolomitic limestones, dolomites, and calcareous shales which weather unevenly on the faces of the ranges. A band of conglomerate, consisting of flattened limestone fragments with a dolomitic cement, is a characteristic bed in the lower part of this formation, as is also a band of yellow siliceous shale. Near the base of the mountain lying north of the Brazeau, and shewn on the corner of the map, were seen some red and pink beds, which contain considerable amounts of iron oxide and iron carbonate deposited about rounded quartz grains as centres. At this point the formation rests on beds of blue homogeneous limestone which may represent the top of the Castle Mountain series, but no fossils were found to prove their Cambrian or Cambrian-Silurian age.

The Lower Banff limestones consist of thick beds of blue limestone, with some dolomitic and siliceous concretions. Many veinlets of calcspar traverse the different layers, and fill spaces once occupied by the shells of brachiopods and other fossils; but the material is usually so coarsely crystalline that all traces of organic structure have been destroyed. Owing to its homogeneity this limestone weathers into bold cliffs, which have often nearly vertical faces.

Age and Thickness.—Some fossil shells found in the upper part of the Lower Banff limestone were well enough preserved to be identified, and these prove its Devonian age. The combined thickness of the Intermediate beds, and the Lower Banff limestone, was measured roughly by calculating the elevations of two points plotted from photographs. These points were picked, one at the top of the mountain north of the Brazeau, which is capped by the Lower Banff limestone, and the other near its base, about the top of the blue limestone supposed to represent the top of the Castle Mountain group. T. [illegible]erence in elevation is 3,25[illegible] feet, and as the beds are nearly [illegible]ontal these figures should correspond closely with the thickness of the two formations.

LOWER BANFF SHALES, UPPER BANFF LIMESTONES, AND ROCKY MOUNTAIN QUARTZITES.

Distribution.—The Lower Banff shales, the Upper Banff limestones, and the Rocky Mountain quartzites are grouped on the map since it was not practical to separate them. The line between the shales and limestones has never been accurately fixed, and the quartzites are very thin, having in the measured section a thickness of only 74 feet. The greater part of the Bighorn range consists of these formations. They form its summit from the Saskatchewan to the Wapiabi Creek gap, but they are finally overlaid by the Upper Banff shale before the end of the range is reached.

Lithological Characters.—The Lower Banff shale consists of calcareous, and yellowish, arenaceous shales, having at the base a band of coal-black fissile quartzite, which breaks into regular cube-like blocks. This band has been recognized at different points in the mountains northward from near the head of the Elk river, in latitude 50° 30′, so that it constitutes a good horizon marker. The Lower Banff shale weathers easily, producing talus-covered ledges on the cliffs bordering the transverse valleys; and where the dip is so steep that it is impossible to ascend the bare smooth faces of the limestone strata, these ledges often form the only means of climbing the mountains on either side.

The Upper Banff limestones are usually whitish in colour, but dark shaly bands occur throughout the formation, and have a much greater development in the Bighorn basin than in the interior ranges of the mountains where the formation was first studied. Lines of cherty concretions occur in the limestones running parallel with the planes, and an abundance of crinoid stems is characteristic of the formation.

Age and Thickness.—The Lower Banff shale is doubtfully referred to the Carboniferous on the evidence of a badly preserved spirifer. Fossils have several times been described from the Upper Banff limestone, proving its Carboniferous age, but there is some doubt as to the precise horizon it represents. No fossils well enough preserved to admit of determination have been found in the Rocky Mountain quartzites, and their reference to the Permian is based solely on their stratigraphic position between Carboniferous and Triassic strata. There is no evidence of an unconformity between this formation and either the Upper Banff limestone below or the Upper Banff shale above, but since a hiatus in sedimentation may have occurred, the Rocky Mountain quartzites may represent any horizon from the mid-Carboniferous to the mid-Triassic.

The combined thickness of the Lower Banff shale, Upper Banff limestone, and Rocky Mountain quartzite, as measured by means of points plotted from photographs, amounts to 1,300 feet. Mr. McConnell measured about 3,500 feet of strata on the Bow river, referable to these formations, but in the third range of the mountains, just south of the Clearwater river, their thickness amounts to only about 2,000 feet. It is apparent, therefore, that the beds thin out to the north.

UPPER BANFF SHALES.

Distribution.—The Upper Banff shales flank the spurs of the western side of the Bighorn range, extending to various distances up their slopes. A little north of the gap of Chungo creek the Upper Banff shales rise to the top of the range, and cap it from there to its northern end.

Lithological Characters.—The Upper Banff shales are arenaceous, calcareous, and sufficiently ferruginous to give the strata a characteristic reddish brown colour when weathered. On fracture, however, they are dark grey. The shales occur in beds of from 2 feet down to about $\frac{1}{10}$ of an inch in thickness, and the thin and thick-bedded varieties alternate several times through the formation. The band of cream coloured limestone—No. 7 in the detailed section—was not noted at any point farther south, and may represent the beginning of a change in the conditions of sedimentation.

Rain drop impressions and ripple marks are common throughout the formation and bear witness to its shallow water origin.

Age and Thickness.—Though a number of badly preserved fossils had previously been found in the formation, its Triassic age was only proved last year by the determination of some better specimens found by Mr. Dowling, a short distance northwest of the basin, on a branch of the Brazeau river. A list of these fossils is given below with those collected by the writer's party. The thickness of this formation—293 feet, as measured in the detailed section—is much less than that found along the main line of the Canadian Pacific railway[1] by Mr. McConnell.

FERNIE SHALES.

Distribution.—The Fernie shales outcrop along the line of the depression between the Bighorn range and the first longitudinal ridge.

[1]G.S.C. Annual Report, Vol. II, 1886, Part D, pp. 17-18.

They are also exposed immediately under the first range of the mountains. This exposure is situated in, and for a short distance north of the valley of the most westerly stream draining from the basin to the Saskatchewan.

Lithological Characters.—The predominating rocks of this formation consist of soft calcareous shales, dark grey or nearly black in colour. The quartzose sandstone—No. 8 in the detailed section—has not been noted at any point south of the basin. It consists of well-rounded quartz grains, including some rounded fragments of the underlying shales in the lowest bed. Some other variations in different districts, in the character of this formation, are worthy of remark. In the third longitudinal valley of the mountains, between the Red Deer and the Clearwater rivers, the Upper Banff shale is overlain by a series of soft yellow dolomites, black calcareous sandstones, and a bed of opal-like quartzite similar to some beds of the Rocky Mountain quartzite. In the first longitudinal valley, north of the Red Deer river, only the second of these three is represented, and, with the exception of the quartzose sandstone, the section there is very similar to that occurring in the Bighorn basin.

Age and Thickness.—The fossil evidence shows that the beds are of somewhat early upper Jurassic age, and does not support the supposition that the bed of quartzose sandstone might mark a pronounced break in the sedimentation. The thickness of the formation in the Bighorn basin—722·5 feet—is much less than farther south in the third longitudinal valley in the Rocky mountains. Between the Red Deer and the Clearwater rivers in this valley, the thickness is about 2,900 feet, and on the Cascade river near Bankhead it is 2,600. In the Moose Mountain district, on the other hand, the thickness is less than in the Bighorn basin—amounting to only 250 feet.[1]

It was found difficult to determine the correct stratum at which to draw the line between the Fernie shales and the succeeding Kootanie formation. In the mountains from the Crowsnest field to the Clearwater river, the lowest bed of the Kootanie consists of a massive sandstone at least a hundred feet in thickness, and, though some thin beds of sandstone occur at intervals in the black shales underlying it, there is no doubt that the thick bed represents a change in the conditions of deposition. In the Bighorn basin there is no

[1] D. D. Cairnes, G.S.C. No. 968. Moose Mountain district, p. 33.

such sudden change, but the thin beds of sandstone increase gradually in thickness until massive beds over 40 feet in thickness are reached. In the detailed section, given above, the line of division has been drawn at the base of a sandstone bed, 10 feet in thickness, which could be recognized with some certainty in different parts of the basin.

KOOTANIE COAL MEASURES.

Distribution.—The Kootanie coal measures form the greater part of the first longitudinal ridge just inside the Bighorn range, and the lower slopes of the line of hills flanking the Saskatchewan valley on the north. From these the outcrop of the formation bends round as it is brought up in the western limb of the syncline, and strikes northwest, but before the Bighorn river is reached it is completely overridden by the older strata of the first range of the Rocky mountains. The formation reappears again a short distance south from the Brazeau, outcropping on both sides of Opabin creek. In the Brazeau valley it is entirely concealed by drift, and this is largely the case in the Saskatchewan valley. The measures outcrop in the cañon of Bighorn river and on the south bank of the Saskatchewan opposite the mouth of the more westerly of the two small tributaries from the north. South of the Saskatchewan, and opposite the end of the Bighorn range, the strata of this formation form an anticlinal ridge.

Lithological Characters.—The strata of the Coal Measures consist of black shales, shaly and siliceous sandstones, coal seams, and a few beds of conglomerates. The pebbles of these conglomerates consist of chert, sometimes green, grey, or pink in colour, though dark blue ones greatly predominate. The pebbles are small and well assorted as to size, and are invariably well rounded. The cement is siliceous.

Unlike the other formations in the basin the strata of the Kootanie show an entire want of regularity, the beds differing in thickness and character in localities situated at short distances from one another. The similarity of the different beds of shales and sandstones, which are repeated again and again as though from the recurrence of practically the same conditions of sedimentation, makes it impossible to recognize, with any certainty, the different horizons in the measures. This adds greatly to the difficulty of tracing the different coal seams, and in the attempt to discover reliable horizon markers, two partial sections of the formation were measured—in addition to the complete one given above. The lowest 700 feet of the measures were measured on George creek, with the following result:—

		Feet.
No.	1. Coal..	1·9
	2. Black shale..	5
	3. Shaly sandstone..	10
	4. Black shale..	59
	5. Coal..	1
	6. Black shale..	6
	7. Shaly sandstone..	10
	8. Brown and black shales..	59
	9. Brown sandstones, separated by beds of black shale	14
	10. Siliceous grey sandstone..	8
	11. Black shale carbonaceous in parts with rain drop impressions..	16
	12. Brown shaly sandstone..	36
	13. Black carbonaceous shale..	29
	14. Heavy beds of sandstone, with brown shale intervening..	138
	15. Heavily bedded siliceous sandstone..	40
	16. Black shale, with a few bands of shaly sandstone...	84
	17. Siliceous sandstone..	10
	18. Black shale and shaly sandstone partly concealed....	129
	19. Brown shaly sandstone and black shale..	58
	Total..	713·9

The other section, on the branch of the Wapiabi creek, extends down from the base of the Dakota sandstone, and is as follows:—

		Feet.
No.	1. Black shale, partly concealed..	389
	2. Shaly sandstone..	3
	3. Black shale..	57
	4. Shaly sandstone..	4
	5. Black shale..	36
	6. Fossiliferous band with shells of nuculoids and gastropods..	0·6
	7. Black shale with concretionary bands..	84
	8. Succession of shaly sandstones separated by black shales..	106
	9. Black shale with fossil plants..	12
	10. Hard siliceous sandstone..	30
	11. Shaly sandstones separated by black shales..	218
	12. Conglomerate bed, pebbles chiefly of blue chert..	6
	Total..	945·6

The bands of conglomerate, and the beds containing shells of nuculoids, might be used as horizon markers if their position relative to the top or bottom of the formation were constant. This is not the case, however. In the hills north of the Saskatchewan two bands of conglomerate occur, one less than 100 feet from the base of the succeeding Dakota formation, and the other near the bottom of the measures. The section just given shows the position of one of

PLATE VII.

Photograph illustrating contemporaneous erosion in the Kootanie formation on Chungo creek.

these bands 940 feet below the base of the Dakota on Wapiabi creek, and another band was seen on that creek a short distance below the point at which this section was ended. On George and Chungo creeks only a single band occurs, about the middle of the measures, but on the hills east of the latter creeks, there are two bands separated by about 300 feet of strata.

A bed of fossil shells occurs about 1,240 feet from the base of the Dakota on Chungo creek, and a similar bed occurs at about the same position on George creek, where it is in the most productive portion of the measures. On Wapiabi creek, however, the only bed of fossil shells seen occurs 490 feet from the Dakota, and on Bighorn river a similar bed occurring near the head of the cañon seems to be at a somewhat lower horizon.

The stratigraphic irregularity may have been caused partly by the action of contemporaneous erosion, as an example photographed on Chungo creek seems to indicate. A bed of sandstone on the eastern bank is abruptly replaced by shale near the level of the stream, and the curved end of the sandstone suggests that the deposit of sand once extended farther. While the material was still unconsolidated, part of the sand was doubtless removed, probably by an eddy, and clay deposited in its place.

Age and Thickness.—The name Kootanie [illegible] used by Dr. Dawson in 1885 to designate the coal-bearing series [illegible] Cascade basin. As will be seen from the palaeontological evidence [illegible] is some doubt whether the formation should be assigned to the bottom of the Cretaceous or to the top of the Jurassic.

The thickness of the Kootanie formation in the basin is over 3,600 feet, which is much greater than might be expected, for at all points where it and the underlying formations have been studied in parallel basins in the eastern Rockies, or in the foothills, the Kootanie and these older strata thin out rapidly eastward. The following measured thicknesses of the Kootanie illustrate the eastward thinning, and it will be noted that in the more northerly examples, which are situated within 50 miles of the Bighorn basin, the thinning is not so pronounced as in the more southerly ones. In the Crowsnest field Mr. McEvoy measures 4,736 feet of strata,[1] of which all but the last measurement, viz., 1,060 feet of black and brown shale, probably be-

[1] G.S.C. Annual Report for 1900, Part A, pp. 87-88.

long to the Kootanie. In the Frank field situated east of the Crowsnest, the thickness of the Kootanie probably does not greatly exceed 742 feet, which is the thickness of a section measured by Mr. W. W. Leach.[1]

Between the Bow and the Kananaskis the thickness of the Kootanie is probably about 2,800 feet, but the uppermost beds have been removed by erosion. In the foothills a short distance to the southeast, the thickness as given by Mr. Cairnes amounts to only 375 feet.[2] In the third longitudinal valley, between Red Deer and the Clearwater, at least 2,300 feet of Kootanie strata have escaped erosion, which has removed the uppermost beds; but in the first longitudinal valley a little south of the Red Deer the total thickness of the formation is only about 1,700 feet.

DAKOTA SANDSTONES AND SHALES.

Distribution.—The Dakota formation outcrops on the western slope of the first longitudinal ridge extending from the Brazeau to the Bighorn valley. The Dakota caps the two most easterly of the line of hills north of the Saskatchewan and west of the Bighorn, but its outcrop is lower on the slopes of the third, where the strata are comparatively flat at the axis of the syncline which traverses the basin from end to end. West of the axis, which is situated a little east of the mouth of the western tributary to the Saskatchewan, the outcrop of the Dakota formation swings round, and as the dip of the strata is very steep the line of its outcrop is nearly straight, and continues northward until it is overridden between the two branches of Bighorn river by the strata of the fault block comprising the first range of the Rocky mountains. The formation emerges from under the mountains on the south side of Opabin creek, but on the north side, and in the Brazeau valley, it appears to be completely buried by drift. The Dakota also outcrops for about 3 miles on the walls of the gorge cut by the Saskatchewan below the mouth of the more easterly of the two small tributaries mentioned. Since an isolated exposure was seen south of the gorge it is probable that it underlies much of the broad valley bottom. The Dakota formation also out-

[1] G.S.C. Summary Report for 1909, pp. 171-173.
[2] G.S.C. No. 968, Moose Mountain District, by D. D. Cairnes, p. 32.

crops on the western slope of the anticlinal ridge which lies south of the Saskatchewan, and opposite the end of the Bighorn range.

Lithological Characters.—The boundary between the Kootanie and Dakota is quite distinct lithologically. The Dakota begins with a bed of white quartzose sandstone, which has a peculiar greenish cast. The grains of this sandstone are not so firmly cemented as those of the siliceous sandstones in the Kootanie, which weather either to reddish or bluish-grey colours. The shales which follow the sandstone are even more easily distinguished, for they weather to reddish and yellowish tints, showing in places a purplish cast, whereas the shales of the Kootanie are almost invariably carbonaceous, to some extent at least, and seldom lose their black colour on weathering. Higher up in the Dakota the sandstones often weather brown, but are usually grey on fracture.

Age and Thickness.—The formation is referred to the Dakota from its almost certain correlation with very similar beds overlying the Kootanie in the Moose Mountain district, which have been described by Mr. Cairnes, and referred to the Dakota horizon from their stratigraphic position and from the evidence of a number of fossil plants. The identity of the two formations is made almost certain by the occurrence on Panther creek of a few beds overlying the Kootanie, which bear the closest resemblance to the Dakota described by Mr. Cairnes, and to the formation overlying the Kootanie in the Bighorn basin. Impressions of twigs and stems of plants were seen in the Dakota, but no determinable fossils. The thickness of the formation is 1,800 feet, which corresponds well with the maximum thickness of 1,700 feet measured by Mr. Cairnes.[1]

BLACKSTONE SHALES.

The remaining four formations in the basin have been given local names. As a series, and lithologically, they resemble closely the corresponding formations which Mr. Cairnes has described from the Moose Mountain district, but the fossil evidence goes to show that they are not the same.

Distribution.—The first of these formations is the Blackstone shales, named from Blackstone creek. These shales occupy the

[1] G.S.C. No. 968, Moose Mountain District, by D. D. Cairnes, p. 31.

greater part of the hollow between the first and second longitudinal ridges. They outcrop above the Dakota sandstone on the third hill north of the Saskatchewan, and like it they swing round and are overridden by the faulted mountain range near the northern branch of Bighorn river. The remaining outcrops are unimportant, as the greater part of the formation is concealed by drift.

Lithological Characters.—The formation is very homogeneous, consisting throughout of dark grey calcareous shales.

Age and Thickness.—No fossils were found in these shales, though a careful search was made. They probably correspond with the lower part of the Benton. The only complete section across the shales is on the more southerly of the two main branches of Wapiabi creek, and there the beds are crumpled, as would be desirable could a better section be obtained.

BIGHORN FORMATION.

Distribution.—The Bighorn formation is named after Bighorn creek, on which it outcrops just below the junction of the two branches. The Bighorn formation outcrops in the second longitudinal ridge between the Bighorn and the Brazeau valley, on the two low ridges between the Saskatchewan and the Bighorn, and on the detached hill between the two branches of the latter river. The formation is overridden by the fault block a short distance north of the northern fork of the Bighorn, but reappears near the head of the northern tributary of Wapiabi creek, and continues in a slightly sinuous line to the southern bank of Opabin creek, beyond which its outcrop is concealed by drift. The Bighorn formation also caps the summit of the third hill in the line west of the Bighorn and north of the Saskatchewan, while south of the latter it outcrops in a ridge a short distance west of the anticlinal ridge opposite the end of the Bighorn range.

Lithological Characters.—The Bighorn formation consists of siliceous and shaly sandstones, black and brown shales, and several bands of conglomerate, which, like the rest of the formation, bears a strong resemblance to corresponding strata occurring in the Kootanie formation.

Age and Thickness.—The only well preserved fossils found in this formation were specimens of *Inoceramus umbonatus*, but a few ribbed shells, probably cardia, were also seen. The horizon is Colorado; the thickness is 390 feet.

WAPIABI SHALES.

Distribution.—The Wapiabi shales occur in the depression west of the second longitudinal ridge and between it and the third ridge, or between it and the mountains where this ridge is absent. The formation is generally concealed by drift, the best exposures being seen on the more southerly of the two main branches of Wapiabi creek, from which it has been named. As a rule, thin exposures of the formation can be seen immediately below the succeeding Brazeau formation, and in some places beneath the limestone of the mountains, but in no place is a complete section exposed.

Lithological Characters.—The Wapiabi shales are brown or dark grey, and somewhat arenaceous. They are very similar to the Blackstone, but contain concretions, and about 800 feet from the base the shales are quite fossiliferous, containing large numbers of a new species of scaphites, and other marine fossils.

Age and Thickness.—The horizon indicated by these fossils is Colorado, and seemingly high up in the Colorado near the base of the Montana. The thickness of the section measured amounted to over 1,300 feet, and the total thickness is probably not far short of 1,800 feet.

BRAZEAU FORMATION

Distribution.—The Brazeau formation is named from the Brazeau river, on which it outcrops, a little north of the edge of the map. This formation caps the third longitudinal ridge, and the flat-topped hill south of the Bighorn. South of the Saskatchewan this formation caps three hills bordering the valley. The eastern of these hills is situated opposite the mouth of Bighorn river.

Lithological Characters.—The Brazeau formation consists of alternating beds of black and brown shales, with greenish-grey sandstones containing pebbles of chert. The lower beds are very similar to those of the Kootanie and Bighorn formations, and the pebbles in the conglomerates from the three formations seem identical. In the upper part of the Brazeau formation, however, the relative abundance of the different coloured pebbles changes, and the dark blue pebbles become fewer than the grey. The blue pebbles greatly predominate.

however, in the lower beds of the Brazeau, as well as in the Bighorn and Kootanie formations. This change is accompanied by an alteration to greyish, greenish, brownish, and yellowish tints in the sandstones, and to brownish and yellowish tints in the shales; except for the bands of conglomerates, the upper part of the Brazeau formation is very similar to the Dakota.

Age and Thickness.—Obscure lamellibranchs, and probably unios and cardia occur in this formation in certain localities. The best specimens were seen on the hill opposite the mouth of Bighorn river, but none were secured. Some impressions of plants also occur.

The section measured is nearly 1,700 feet, but this does not represent the true thickness of the formation, since the top has been removed by erosion.

GLACIAL AND RIVER DRIFT.

Distribution.—The glacial and river drift have been grouped together, since at present it is impossible to separate them over large portions of the basin. They form thick sheets in the Saskatchewan and Brazeau valleys, and also in the third longitudinal depression, where they are trenched by streams to a depth of over 100 feet without bed-rock being exposed. A large part of the Bighorn valley is buried under drift, as is also the transverse valley extending to the Wapiabi Creek gap through the Bighorn range. The boundaries of the drift are only approximate, and rock exposures may occur at a number of points which escaped notice.

Lithological Characters.—The glacial drift consists chiefly of boulder clay, though parts of it have been partially re-sorted by fluvial action, in which case it is very difficult to distinguish it from the river gravels forming at the present time. Except near the Saskatchewan and Brazeau valleys, the stones and boulders in the boulder clay all belong to formations occurring in the basin, but in these valleys, and even high up on the slopes of the mountains immediately adjoining them, stones and boulders from the conglomerates of the Castle Mountain series were recognized by the presence of large feldspar fragments. As far as is known, the Castle Mountain series does not outcrop closer than 20 miles from the basin, and the peculiar distribution of the debris shows that large glacial tongues must have descended the Saskatchewan and Brazeau valleys and overridden portions of the adjoining mountains.

The greater part of the river drift deposited by the main rivers and their tributaries consists of coarse gravel, but both the Saskatchewan and Brazeau are rendered turbid during warm weather by the amount of fine silt they carry from the large glaciers at their heads. Before the Saskatchewan cut the gorge already mentioned, through the Dakota formation, it made large deposits of this silt, which cover much of its valley immediately east of the mountains. These deposits answer well to the description of loess, weathering to steep cliffs, and supporting comparatively little vegetation. During the high winds in September and October these deposits become the source of much dust, which so fills the air that from the other side of the basin it has been mistaken for smoke from a forest fire. Lower down the river, about the mouth of the lower of the two small tributaries, dunes of this material have been built by the wind.

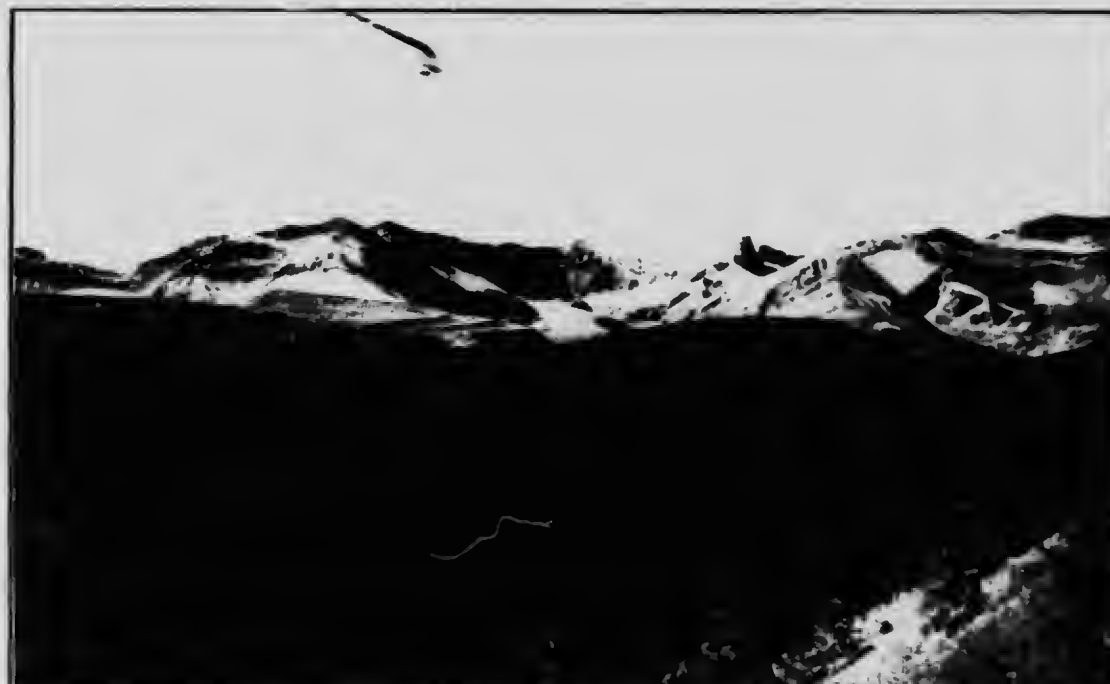
Structural Geology.

Major Structural Features.—The general geological structure has already been sketched. The Bighorn and the first range of the Rocky mountains are huge fault blocks, tilted and thrust to the northeast until Devonian strata at their base have overridden Jurassic and Cretaceous. Along the southwestern side of the basin all the formations between the Upper Banff shales and the Brazeau formation come into direct contact with the Intermediate beds at the base of the first range. The throw of the fault east of the Bighorn range is sufficient to bring Intermediate beds into contact with Wapiabi shales near the middle of the range, but the amount of the throw decreases rapidly near its ends. This decrease is much more rapid at the southern end of the range, where it is accompanied by a sudden change in the direction of the dip of the beds. To within 5 miles of the end of the range the dip shows but little deviation from the southwest direction which is general throughout the rest of the range, but at the end it has swung round to nearly directly south. This sudden change has probably induced some of the minor structural irregularities which will be described later.

The angle of dip of the strata in the Bighorn range varies between 35 and 60 degrees, and, as a general rule, the angle of dip of the younger strata in the basin west of it decreases gradually until the axis of the deep syncline traversing the basi[illegible] reached. Just west of the axis the change in dip is abrupt, and the strata of the western limb are generally nearly vertical, or have been overturned so as to dip to the southwest like those of the eastern limb, though usually at much higher angles. In extreme cases [illegible] southwesterly dip may be as low as 60 degrees. The shar[illegible] of the fold has resulted in the thinning out of the softer shale form[illegible] a great deal of crumpling among the harder beds.

While the main syncline traverses the [illegible] on the Saskatchewan to the Brazeau, there are also some [illegible] which produce local flattening in the strata, form[illegible] [illegible]ern lin[illegible] and even in some cases low dips to the east [illegible] later, as some irregularities in the stru[illegible] syncline should be described first. These irregular[illegible] ar[illegible] by the relative positions of the outcrops of strata belon[illegible] different formations which are situated along the axis of the syncline, as shown by the very low angles of dip. The line of the axis deviates considerably from a northwest and southeast direction, and in places it pitches sharply, sometimes to the one and sometimes to the other of these directions. On the Saskatchewan the axis is indicated by flat lying basal beds of the Dakota formation outcropping at the top of the gorge which has been mentioned. The flat lying beds of the Bighorn formation, which cap the hill to the northwest, represent the continuation of the axis, and as the height of the hill is about 2,800 feet above the river—a figure which corresponds closely with the combined thickness of the Dakota and Blackstone formations—it is evident that the axis of the syncline is approximately horizontal between these two points. The next point where the exact position of the axis can be determined is the flat hill capped by the Brazeau formation 2 miles south of the Bighorn. This hill is slightly higher than the one capped by the Bighorn formation, but the combined thickness of the Bighorn and Wapiabi formations—which is certainly not less than 2,000 feet—shows that between the two hills the axis of the syncline dips sharply to the northwest, and there is also a swinging of the line of the axis towards the west, though this is not very pronounced. The pitch to the northwest continues to the Bighorn river, where bottom beds of the Brazeau formation outcrop only about 200 feet above the valley bottom. To the northwest of the

PLATE VIII.



Near view of the first range showing also the syncline in the Brazeau formation.

Bighorn, however, the pitch of the syncline is reversed, and at the next point, where the position of the axis is certain, the base of the Brazeau formation outcrops at an elevation nearly 1,000 feet greater This point is situated at the end of the third longitudinal ridge distant about 5 miles from the Bighorn. To the northwest the axis is not again indicated by outcrop for 6 miles, until the three small detached hills between the branches of George creek are reached. These are capped by the Brazeau formation, and their position shows that the line of the axis has swung round a little from the westward, though there is no evidence of any decided pitch. From the third of the three hills, however, the line of the axis swings suddenly to a more northerly direction, and then pitches sharply to the north northeast, so that the Brazeau formation outcrops in the bank of the Brazeau river at an elevation more than 2,000 feet lower than on the hills just mentioned.

The overriding of different formations by the Intermediate beds at the base of the fault block comprising the first range of the Rockies is probably caused chiefly by the irregular outline of the range, though partly by the crooked axis of the syncline which converges with and diverges from the plane of the fault. It is not certain, however, that this fault plane is straight, nor that it has a regular dip, though this appears to be the case.

Minor Structural Features.—The strata in the first range of the Rockies show many crumples, which doubtless are a continuation northward of the displacements giving rise to the two ranges into which the first range divides south of the Saskatchewan. Fewer crumples occur in the strata of the Bighorn range, but a well developed example of an overturned anticline was observed on the eastern edge of the range 3 miles south of the Wapiabi Creek gap.

Allusion has already been made to minor flexures affecting the strata of the eastern limb of the deep syncline which traverses the basin. The most important of these is a shallow flexure, which occurs in the valley of the Bighorn, crossing that stream about half a mile above the falls. The axis of the flexure is not straight, but shows a broad curve convex to the northwest, and, though it has not been traced through, it probably is connected with the crumple in the Bighorn range just mentioned. In the Bighorn valley the flexure is pronounced enough to induce dips as high as 35 degrees to the south-cast, and the great width of the outcrops of the Kootanie and Dakota formations in this vicinity is caused by this reversal of the strata. Other smaller flexures were indicated by a local flattening of the dip of the Bighorn formation near the junction of the two main branches of George creek, and of the Brazeau formation in the third longitudinal ridge between two branches of Blackstone creek. The direction in which these flexures run was not determined.

In addition to the flexures there are a number of lines of sharp crumples, often accompanied by the development of small faults. These are especially important from an economic point of view, since the Kootanie coal measures are affected by them to a very marked degree. They will, therefore, be treated under the head of economic geology.

Palæontology.

Eight horizons are represented in the collection of fossils determined. The collection included a few specimens from the Upper Banff shale, collected by Mr. Dowling from a branch of the Brazeau river a few miles northwest of the basin. The horizons are given in ascending order, with the determinations and remarks of the palæontologists to whom they were sent for examination.

Horizon.—Uppermost beds of the Lower Banff limestone.

Determination and remarks by Professor Charles Schuchert.

Schuchertella chemungensis, (Conrad)?
Martinia richardsoni, Meek.
Spirifer disjunctus, *var. animasensis*, Gertz.

'These are all forms of the Upper Devonic, and the latter is characteristic of the western Meodevonic.'

Horizon.—Lower part of the Lower Banff shale.

Professor Schuchert's remarks are as follows:—

'The *Spirifer* is undeterminable. It looks more like Mississippic types than Devonic, but the preservation is so poor that I cannot say anything definite.'

Horizon.—Upper Banff shale.

Professor Schuchert's determinations and remarks are as follows:—

Monotis circularis, Gabb.
Posidonomya sp. undet.

'The smaller specimens referred to *Monotis circularis* remind me somewhat of *Halobia occidentalis*. The horizon is Triassic and probably upper Triassic.'

HORIZON.—Fernie shale below the bed of quartzose sandstone.

Professor Schuchert's determinations and remarks are as follows:—

Inoceramus sp.
Ostrea engelmanni, Meek?
Pseudomonotis (Eumicrotis) curta, Whitfield?
Belemnites macritatis, White.

'The Ostrea is only about one-fourth the size of the type specimen. It is not *Ostrea strigilecula*. The *Pseudomonotis* is much larger than the Black Hills specimens. The *Belemnite* is far more slender than *B. densus*. Horizon in Stanton and Martin's Nahnek of Alaska, and probably the equivalent of the Sundance of Wyoming, or possibly somewhat older early upper Jurassic.'

HORIZON.—Fernie shale immediately above the bed of quartzose sandstone.

Professor Schuchert's determinations and remarks are as follows:—

Inoceramus sp.
Avicula wyomingensis, Stanton (*A. mucronata*, Meck and Hayden, not of Gabb).
Camptonectes sp. undet.
Ostrea (Alectryonia) sp. undet.
Gryphaea calceola var. *nebrascensis*, Meek and Hayden.
Belemnites skidegatensis, Whiteaves?
Sphaeroceras cephoides, Whiteaves?
Phylloceras ? a fragment.

'The *Belemnite* is probably a new species, as it has three apical sulci instead of one as in Whiteaves' species. Horizon same as previous one.'

HORIZON.—Lower half of Kootanie formation.

Dr. F. H. Knowlton's determinations and remarks are as follows:—

Sequoia reichenbachi (Gein.), Heer.

Taxodium sp.
Podozamites lanceolatus (L. and H), Br.
Sagenopteris sp.

'Now it happens very unfortunately that both the identified species are found in Jurassic and Kootanie, and so are not good to fix the definite age, though the form of the *Sequoia* present is not to be distinguished from forms figured from the lower Cretaceous. *Sagenopteris* has not hithertofore been reported from the Kootanie, but is represented in the Shasta flora, which is of similar position. The *Taxodium*, however, if I have identified it correctly, has not, I believe, been found in the Jurassic. The matrix suggests Jurassic, but this is, of course, not of much importance. On the whole I would rather incline to put them in the Kootanie, but I should not be very positive about it.'

HORIZON.—About the middle or higher in the Kootanie formation.

Doctor Stanton's determinations and remarks are as follows:—

Astarte?
Pleuronomya?
Amberleya?
Pseudomelania?

'The invertebrates have proved very puzzling, since they differ specifically, and as an assemblage, from all faunas known to me from that general region. The most surprising thing about them is the fact that they appear to be a marine fauna, whereas the Kootanie has always been considered a fresh-water formation. It is true that judging from the external character—which is all we have in most cases—several of the species might be referred to fresh-water groups, but there are several specimens of the bivalves which show portions of the hinge and other external characters that are different from any known fresh-water shells, and necessitated their reference to the *Astartidæ*, a marine family. While there is not enough in the present collection to decide whether the fauna is Jurassic or Cretaceous, there are some features in it rather suggestive of Jurassic age.'

HORIZON.—Base of the Bighorn formation.

Professor Schuchert's determination and remark on it is as follows:—

Inoceramus umbonatus, Meek and Hayden. Horizon, Colorado.

HORIZON.—About 800 feet above the base of the Wapiabi formation.

Professor Schuchert's determinations and remarks are as follows:—

Inoceramus labiatus, Ichlothum.
Inoceramus umbonatus, Meek and Hayden.
Scaphites n. sp.
Avicula linguiformis, Evans and Schumard?
Belemnitella manitobensis, Whiteaves?

'The fragment of the *Belemnitella* is so small that one cannot make out all the characteristics characters. The *Scaphites* are the largest Colorado specimens of this group known to me. They attain to nearly 4½ inches. The horizon of these fossils is clearly Colorado, and seemingly high up in the Colorado near the Montana series.'

Correlation.

In the following table the geological section in the Bighorn basin is compared with Mr. McConnell's section in the mountains along the main line of the Canadian Pacific railway, and Mr. Cairnes' in the foothills south of that line. Since, as yet, no evidence has been found in the foothill region, or in the Bighorn district, of unconformities in the upper Cretaceous, it seemed natural to correlate the corresponding members of two series of strata which strongly resemble each other lithologically. The correlation of the older members of the series from the Dakota down, is rendered certain by their almost continuous exposures from the Canadian Pacific railway north to the Bighorn basin; and, as has been stated, the Dakota formation was recognized on Panther creek about half way between the two localities. The fossil evidence opposes the correlation of the remaining four formations as suggested by the table, and seems to indicate that at least the Wapiabi, Bighorn, and Blackstone formations of the Bighorn basin, with a total thickness of about 3,240 feet are represented in the foothills by the Benton shales and Cardium sandstones, with a total thickness of only 1,020 feet; while possibly the Brazeau formation should also be considered to be of Colorado age, though its resemblance to the Judith River beds, as described in the foothills, is very striking. This table is as follows:—

CORRELATION OF SECTIONS ON LITHOLOGICAL RESEMBLANCES.

Bighorn Basin.	Mountains near C.P.R.	Foothills.
Brazeau formation, 1,680 feet	....	Judith River beds, 1,025 feet.
Wapiabi shales, 1,800 feet...	....	Claggett shales, 300 feet.
Bighorn formation, 390 feet.	....	Cardium sandstone, 220 feet.
Blackstone shales, 1,050 feet.	....	Benton shales, 800 feet.
Dakota formation, 1,800 feet	....	Dakota formation, 1,700 feet.
Kootanie formation, 3,659 feet.	Kootanie formation, 2,800 feet.*	Kootanie formation, 375 feet.
Fernie shale, 723 feet......	Fernie shale, 2,600 feet*...	Fernie shale, 250 feet.
Upper Banff shale, 293 feet.	Upper Banff shale } 700 feet	Not recognized.
Rocky Mt. quartzite, 72 feet	Rocky Mt. quartz. } 700 feet	Rocky Mt. quartzite (not measured).
Upper Banff lime } 1,200 feet	Upper Banff lime, 3,000 feet	Upper Banff limestone (not measured).
Lower Banff shale } 1,200 feet	Lower Banff shale, 700 feet	....
Lower Banff lime } 3,250 feet	Lower Banff lime, 800 feet.	....
Intermediate beds } 3,250 feet	Intermediate beds, 1,500 feet.	....

* Measured by Mr. Dowling near Banff. Mr. McConnell states that the combined thickness of the two formations does not exceed 5,000 feet.

List of Fossils Determined from the Different Formations.

INTERMEDIATE BEDS.

Many corals occur in this formation, but in the great majority of cases the structure has been destroyed by crystallization, induced subsequent to the deposition of the strata. A coral collected by Mr. McConnell from near Laggan was examined by Mr. Lawrence M. Lambe, who reported that it probably belongs to the species *Cladopora cervicornis* (de Blainville), or one closely resembling it.

LOWER BANFF LIMESTONE.

From the Bighorn basin.—

Schuchertella chemungensis (Conrad)?
Martinia richardsoni, Meek.
Spirifer disjunctus var. *animassensie*, Gertz.

LOWER BANFF SHALE.

From the Bighorn basin, a *Spirifer*. From the mountains near the main line of the Canadian Pacific railway, a number of specimens of *Clymenia*.[1]

UPPER BANFF LIMESTONE.

From the mountains between the Red Deer and Clearwater rivers two species of *Rhynchonellids*, one near *R. metallica*, White, and another—the common finely plicated form—near *R. eurekensis*, Walcott. These were determined by Professor Charles Schuchert, in addition to a number of the fossils from the basin given under the heading Palæontology.

A number of other fossils have been determined from the Banff limestone, but the horizons were not clearly distinguished, so that it is likely that they include specimens from the Lower Banff shales, and Lower Banff limestone. The list is as follows:—

From the Athabaska river.—A *Syringopora* like *S. perelegans*, and another like *S. nobilis, Reticularia setigera? Productus*—very fine ribbed—*Spirifer* sp., *dielasma*, (cf. D. Formosa, Hall).[2]

From the mountains near the main line of the Canadian Pacific railway.—A *Rhynchonella* like *R. rocky montana*, another like *R. metàllica. Atrypa recticularis*, and a *Spirifer* like *S. whitneyi.* Also a species of *Athyris, Productus, Lichas, Eridophyllum*, and *Diphyllum.*[3]

UPPER BANFF SHALES.

From a branch of the Brazeau river.—*Monotis circularis*, Gabb. *Posidonomya* sp. undet.

From the main line of the Canadian Pacific railway.—Specimens of *Aviculopectens*, and *Lingulae.*

FERNIE SHALES.

From the Bighorn basin.—*Inoceramus* sp.; *Ostrea engelmanni*, Meek; *Pseudomonotis (Eumicrotis) curta*, Whitfield ? *Belemnites macrilatis*, White; *Avicula wyomingensis*, Stanton, (*A. mucronata*,

[1] G.S.C. Annual Report for 1886. Part D. p. 18.
[2] G.S.C. Annual Report, Vol. XI, Part D. pp. 28-31.
[3] G.S.C. Annual Report. 1886. Part D, p. 19.

Meek and Hayden, not of Gabb); *Campouerles sp. undet.; Ostrea* (Alectryonia) sp. undet.; *Gryphaea calceola* var. *nebrascensis*, Meek and Hayden; *Belemnites skidegatensis*, Whiteaves ? *Sphaeroceras cephoides*, Whiteaves? *Phylloceras?*

From the Red Deer river.—*Peltoceras occidentale*, Whiteaves.[1]

From Minnewanka lake, near main line of the Canadian Pacific railway.—*Terebratula robusta; Ostrea skidegatensis; Exogyra* sp.; *Lima perobliqua; Pteria (Oxytoma); Carneuiliana* d'Orbigny; *Trigonoarca tumida; Trigonia dawsoni; Astarte charlottensis; Protocardia hillana; Cyprina occidentalis: Pleuronomya charlottensis; Schloenbachia borealis; Schloenbachia gracilis.*[2]

From near Fernie.—*Cardioceras canadense.*[3]

KOOTANIE FORMATION.

From near the Smoky river, lat 53° 54′, long. 119° 4′, *Zamites acutipennis* and *Tancredia* sp. These have been determined by Dr. F. H. Knowlton, and Dr. T. W. Stanton of the United States Geological Survey.

From the Bighorn basin.—*Sequoia reichenbachi; Taxodium* sp.; *Podazamites lanceolatus* (I. and II) Br.; *Sagenopteris* sp.; *Astarte* sp.; *Pleuronamya* sp.; *Scalaria* sp.; *Pseudomelania* sp.; *Amberleya* sp.

From Canmore and Anthracite on the main line of the Canadian Pacific railway.—*Asplenium martinianum; Zamites montana: Dioonites borealis: Equisetum lyellii*, Mantell; *Angiopteridium canmorense*, Dawson; *Pecopteris browniana*, Dunker; *Cladophlebis falcata*, Fontaine; *Pinus nordenskioldii*, Heer; *Aspidium fredericksburgense*, Fontaine; *Leptostrobus longifolius*, Fontaine; *Pinus anthraciticus*, Dawson; *Sphenolepidum pachyphyllum*, Fontaine.[4]

From the foothills near Moose mountain.—*Dryopteris fredericksburghensis* (Font.), Knowlt.; *Cycadites longifolis* (Font.), Knowlt.; *Sagenopteris mantelli* (Dunk.), Schenk.; *Athrotaxopsis tenuicaulis*, Font.; *Sagenopteris*, n. sp.; *Thyrsopteris meekiana*, Font.; *Sesquoia*

[1] Description of a Canadian Species of Peltoceras, Ottawa Naturalist, Vol. XXIII, No. 5, 1907.

[2] Contributions to Canadian Palæontology, Vol. I, Part II, pp 163, 171.

[3] Ottawa Naturalist, Vol. XVIII, p. 65.

[4] Trans. Roy. Soc. Canada Sect. IV, 1885. 'On Mesozoic Floras of the Rocky Mts. Region of Canada.' Also Section IV, 1892. 'On the Correlation of Early Cretaceous Floras in Canada and the United States, and on Some New Plants of this Period.' Both papers by Sir William Dawson, LL.D., F.R.S.

heterophylla, Vel.; *S. smittiana*, Heer; *Sagenopteris elliptica*, Font.; *Baieropsis pluripartita*, Font.; *Podozamites longifolius*, Emmons; *Podozamites lanceolatus*, (L. and H.) Schimp; *Thyrsopteris insignis*, Font.; *T. pecopteroides*, Font.; *Cladophlebis falcata*, Font.; *Zamites articus*, Gopp.; *Ginkgo huttoni magnifolia*, Font.; *Cladophlebis constricta*, Font.; *C. distans*, *Font?*; *Nilsonia*, n. sp.[1]

From the Elk River valley near Fernie.—*Diksonia* sp.; *Asplenium martinianum*, Dawson; *A. dicksonianum*, Heer; *A. distans*, Heer; *Dioonites borealis*, Dawson; *Podozamites lanceolatus*, Lindley; *Zamites montana*, Dawson; *Z. acutipennis*, Heer; *Anomozamites acutiloba*, Heer; *Sphenozamites* sp.; *Antholites horridus*, Dawson; *Salisburia* (Ginkgo) *sibirica*, Heer; *S. lepida*, Heer; *S. nana*, Dawson; *Baiera longifolia*, Heer; *Pinus suskwaensis*, Dawson; *Sequoia smittiana*, Heer; *Glyptostrobus groenlandicus*, Heer; *Taxodium cuneatum*, Newberry.[2]

DAKOTA FORMATION.

From the Moose Mountain district.—*Sphaerium* sp.; *Viviparus* sp.; *Goniobasus* sp.; *Campeloma* sp.; *Carpolithus ternatus*, Font.; Fruits probably of: *Ginkgo*, *Sphenolepidium sternbergianum densiflorum*, Heer; *Ginkgo lepida*, Heer; *Ginkgo sibirica*, Heer; *Ginkgo* sp.; male inflorescence, *Athrotaxopsis tenuicaulis*, Font.; *Nilsonia californica*, Font.; *Ginkgo huttoni*, Heer; *Thyrsopteris brevipennis*, Font.[3]

BENTON SHALES (=Blackstone shales?).

From the Moose Mountain district.—*Inoceramus problematicus*, *Scaphites ventricosus*, *Prionocyclus woolgari*?[4]

BIGHORN FORMATION (=Cardium sandstone?).

From the Bighorn basin.—*Inoceramus umbonatus*, Meek and Hayden.

From the Moose Mountain district.—(Cardium sandstone).—*Cardium perpauculum*, Stanton.

[1] G.S.C. No. 968, Moose Mountain District, by D. D. Cairnes, pp. 53, 54.
[2] Trans. of the Royal Society of Canada, Sect. IV, 1885. On the Mesozoic Floras of the Rocky Mountain Region of Canada, pp. 5-10.
[3] G.S.C. No. 968, Moose Mountain District, by D. D. Cairnes, pp. 53-54.
[4] G.S.C. No. 968, p. 53.

WAPIABI SHALES (=Claggett shales?).

From the Bighorn basin.—*Inoceramus labiatus*, Ichlothum; *Inoceramus umbonatus*, Meek and Hayden; *Avicula linguiformis*, Evans and Shumard?; *Belemnitella manitobensis*, Whiteaves?; *Scaphites* n. sp.

From the Moose Mountain district (Claggett shales).—*Linguella subsparulata*, *Pteria nebrascana*, *Baculites compressus*, *Cycadites unjiga*, Dn.[1]

JUDITH RIVER FORMATION (=Brazeau Formation?).

From the Moose Mountain district.—*Populus elliptica*, Newb.; *Betulites* sp.; *Dioonites* sp.; *Asplenium niobrara*, Dn.; *Athrotaxopsis tenuicaulis*, Font.; *Asplenium dicksonianum*, Heer; *Thyrsopteris pecopteroides*, Font.; *Sequoia smittiana*, Heer; *Protophyllum haydenii*, Lecsq.; *Cissites* sp.; *Sequoia cuneata*, Newb.; *Ginkgo baynesiana*, Dn.; *Paliurus cretaceus*, Lecsq.; *Juglans crassipes?*, Heer; *Salix* sp.; *Quercus rhamnoides*, Lecsq.; *Paliurus ovalis*, Dn.; *Angiopteridium strictinerve?*; *Ginkgo sibirica*, Heer; *Sequoia reichenbachi*, Heer; *Sphenopteris johnstrupi*, Heer; *Sequoia ambigua*, Heer; *Alnites grandiflora*, Newb.[2]

As already stated, the evidence presented by the fossils is contrary to the correlation, as suggested above, of the four uppermost formations in the section occurring in the Bighorn basin with that in the Moose Mountain district. The collections from three out of the four doubtfully correlated pairs of formations are too meagre to be of much value, but those from the Wapiabi shales, in the Bighorn basin, and the Claggett shales, in the Moose Mountain district, are more numerous and must be considered before their correlation can be assumed. As will be seen from the above list, the Wapiabi shales contain *Inoceramus labiatus*, *I. umbonatus*, *Avicula linguiformis?*, *Belemnitella manitobensis?*, and a new species of *Schaphites*, fossils which indicate, according to Professor Schuchert, a horizon which is 'Clearly Colorado, and seemingly high up in the Colorado near the base of the Montana.' On the other hand, the Claggett shales from the Moose Mountain district contain *Pteria nebrascana*, and *Boculites compressus*, which are characteristic of the Claggett shales

[1] G.S.C. No. 968, p. 54.
[2] G.S.C. No. 968, p. 54.

and the younger Bearpaw shales, both in Canada and the United States, and which, therefore, belong to the Montana epoch.

Economic Geology.

The economic importance of the Bighorn basin arises solely from the coal seams occurring in the Kootanie formation. As has been stated, the strata of this formation vary along the strike, and owing to this variation it is practically impossible to correlate seams in different parts of the basin. General experience in other fields, where seams belonging to the Kootanie formation have been worked, has shown that the coal seams are more regular than the intervening strata. In one case noted by Mr. McEvoy the total thickness of three seams showed a diminution of from 52 to 46 feet in a distance of 7 miles, while the thickness of the intervening strata diminished from 337 to 102 feet.[1]

Kootanie coals are now being worked at Fernie, Coleman, Blairmore, Frank, Hillcrest, Canmore, and Bankhead; and except in rare instances the seams have been found continuous, unless cut off by crumples or faulting.

NUMBER AND THICKNESS OF COAL SEAMS.

Our knowledge of the number and thickness of the coal seams occurring in the basin is not as complete as might be desired, but, from the list which will be given, at least an approximate estimate of the coal content can be made. It may first be pointed out, however, that in this area it is rather the exception than the rule to find coal seams exposed naturally on the surface, and that, unless the strata have been carefully prospected, the failure to see a seam is no evidence that one is not buried beneath the surface debris which has accumulated in the outcrops of all the softer beds. A case particularly in point is the detailed section of the Kootanie formation given above. Since this section was measured in less than two days, no attempt was made to find all the buried seams, or even to strip for measurement all those whose presence beneath was revealed by pieces of float coal at the surface. In some cases the debris included large blocks of sandstone, which had slid down over the seams. The summarized statement of the seams seen in this section, with each thickness and that of the intervening rock, is as follows:—

[1] G.S.C. Annual Report, Vol. XIII (1900), Part A, p. 90.

Section on Chungo Creek.

	Feet.
Rock..	131
Coal..	2·4
Rock..	2·9
Coal..	4·7
Rock..	161
Coal..	3·9
Rock..	2·5
Coal..	2·4
Rock..	127
Coal..	4·5
Rock..	353
Coal..	6·6
Rock..	288
Coal..	2
Rock..	2,567
Total..	3,658·9
Total coal..	26·5

The only sections in which it is probable that all the seams were seen were those examined by Mr. McEvoy and his party, on George creek and Bighorn river. The banks of the streams were thoroughly prospected by drilling with an iron bar, and all the seams found were cleared of the debris, so that the thicknesses given are accurate. The section on George creek extends down from the first seam, which outcrops a short distance below the base of the Dakota formation. It is as follows, the important seams being numbered:—

		Feet.
	Coal..	0·5
	Rock..	70
No. 1.	Coal..	0·3
	Rock..	1·5
	Coal..	1
	Rock..	40
No. 2.	Coal and shale..	5
	Rock..	60
No. 3.	Coal with three bands shale..	3
	Rock..	0·5
	Coal..	4
	Rock..	110
	Coal..	0·8
	Rock..	240
No. 4.	Coal with three bands of shale 1 inch each..	10·6
	Rock..	110
No. 5.	Coal, dirty at outcrop..	3
	Shale and coal..	0·3
	Coal, one band of shale 3 inches..	4·3
	Rock..	80
No. 6.	Dirty coal..	1·7
	Coal..	1·5
	Shale..	0·5
	Coal, with band of shale 2 inches..	6·7
	Rock..	30
No. 7.	Coal..	1
	Rock..	10

No. 8.	Coal	0·5
	Shale	2
	Coal, with 3 inch shale band, seam locally reduced in thickness	5
	Rock	220
No. 9.	Coal	8
	Undetermined Thickness of Rock and possibly other Seams.	
No. 10.	Coal locally reduced by a crumple	1
	Rock	100
	Coal	1
	Shale	1·5
No. 11.	Coal	9·5
	Rock	90
No. 12.	Coal	12
	Shale	0·2
	Dirty coal	2
	Rock	200
No. 13.	Coal	3
	Rock	150
No. 14.	Coal	3·2
	Rock, about	1,000
	Rock, with seven small seams, 2 feet and under	125
	Total	2,760·1
	Total coal	88·9

The small seams noted at the base of this section are the same as those mentioned at the top of the partial section at George creek which was given in the general description of the Kootanie formation. These are all too small to be worked under present economic conditions.

Mr. McEvoy's other section was measured in the vicinity of the falls on Bighorn river, and includes a smaller part of the measures than the one on George creek. It begins a short distance below the base of the Dakota formation. The important seams are designated by letters.

		Feet.
Seam A.	Coal	5
	Rock	7
Seam B.	Coal	4·5
	Rock	8
Seam C.	Coal	7
	Rock	250
Seam D.	Coal	13
	Rock	130
Seam E.	Coal	2
	Rock	140
	Coal	2
	Shale	0·2
Seam F.	Coal	2·2
	Coal and shale	3
	Coal	6
	Rock with several seams of coal under 2·3 feet	700
Seam G.	Coal	8
	Total	1,287·9
	Total coal	52·7

On page 33 of the Summary Report for 1907 Mr. Dowling gives a list of seams measured on a small branch of Blackstone creek. They are as follows, beginning with the highest: 14 feet 5 inches; 8 feet; 11 feet 9 inches; 4 feet 10 inches; 3 feet 11 inches; 5 feet 10 inches; 5 feet 8 inches; 8 feet 5 inches, and 3 feet 6 inches, giving a total of 66 feet 4 inches. He adds that only about half the measures were prospected. He also mentions the occurrence of four seams, 2·2, 1·9, 7·5, and 5·5 feet thick on the south side of the Saskatchewan.

Three natural exposures of coal were found on Wapiabi creek. The lowest of the three is situated just below the junction of the two main branches, and the others about a quarter of a mile above, on the northern branch. These were measured, with the following results, beginning with the highest:—

Seam No. 1.—Coal 9·3 feet, shale 1 foot, coal 2·2 feet.

Seam No. 2.—Coal 5·2 feet.

Seam No. 3.—Coal 5·4 feet.

Coal was also seen at several points on the hills north of the Saskatchewan valley, including the most westerly hill, where the strata form part of the western limb of the syncline and are nearly vertical. On the southern side of Opabin creek more coal was seen. Here the Kootanie also forms part of the western limb of the syncline, and the beds are overturned, and the seams so badly crushed that they did not permit of measurement.

CHARACTER OF THE COAL.

The following are lists of analyses which have been made of samples and specimens of coal from the basin. The only sampling was done by Mr. McEvoy, who had tunnels driven far enough into the various seams to secure as near as possible samples free from the effects of surface weathering. His analyses represent coal taken across the several seams in equal amount for their full width. Mr. McEvoy made coke from different seams, taking care to use coal fairly representative of the whole width of the seam. The numbered and lettered seams from which Mr. McEvoy's samples were taken correspond with those so designated in his sections given above.

Those lettered are from Bighorn river, those numbered from George creek.

COAL ANALYSES.

(Samples.)

No.	Thickness.	Moisture.	Vol. Comb. matter.	Fixed Carb.	Ash.	Calor. Value, B. T. U.	Sulphur.
A ..	5 feet	0·38	22·62	68·85	8·15	......	......
B ..	4·5 "	0·20	22·95	69·78	7·07	......	......
C ..	7 "	0·32	19·51	71·17	8·70	14,011	0·98
3...	6·7 "	0·28	29·04	64·52	6·16	......	0·68
4...	10·2 "	0·90	27·60	60·08	11·42	......	0·46
5...	4 "	0·34	25·28	68·13	6·25	......	......
8 ..	4·7 "	0·36	26·72	62·35	10·57	......	1·21
11	9·5 "	0·20	24·13	69·34	6·33	14,483	......
12..	12 "	0·56	22·82	70·30	6·32	......	0·69
14..	3·2 "	1·46	24·04	67·93	6·57	......	0·70
6...	6·5 "	0·50	20·10	49·62	29·78	......	0·56
9...	8 "	0·30	24·58	62·95	12·17	......	......

With one or two exceptions coal from these seams cokes, and in most cases its quality is excellent. The following are analyses:—

ANALYSES OF COKES

Number.	Thickness.	Moisture	Fixed Carbon.	Ash.
A.	5 feet	0·06	92·49	7·45
C.	7 "	0·06	91·77	8·17
D.	13 "	0·03	90·77	9·20
F.	7 "	0·03	91·09	8·88
5	4 "	0·04	94·63	5·33
8	4·7 "	0·06	88·71	11·23
9	8 "	0·04	92·23	7·73
11	9·5 "	0·05	93·35	6·60
12	12 "	0·03	90·38	9·69

The following are analyses of specimens of loose coal taken from the outcrop of the different seams. The locality and thickness of the seam is given in each case. Some of the figures represent an average of two or more analyses.

COAL ANALYSES.

(Specimens.)

Locality.	Thickness.	Moisture.	Vol. Comb. Mat.	Fix. Carb.	Ash.	Calor. Val. B.T.U.	Sulp.	Coke.
	Ft.							
South of Saskatchewan river, opposite Bighorn range....	2·2	5·80	25·50	62·60	6·10	......	......	.....
" " "	1·9	3·74	25·50	67·00	3·76	......	...	......
" " "	5·5	1·39	25·59	68·92	4·10	14,041	....	......
" " " ...	7·5	0·79	23·10	68·61	7·50	13,712	0·65	Firm.
Bighorn river above falls....	4·5	0·99	23·17	68·24	7·60	13,448	0·57	"
" "	6	0·87	21·47	70·39	7·27	13,721	0·66	"
Tributary of Blackstone creek.	1·6	2·00	28·55	60·75	8·70	......	......	......
" " ..	14·4	1·85	26·99	62·79	8.37	12,456	0·45	Friable.
" " ..	8	2·04	24·38	62·49	11·09	11,976	0·56	"
" " ..	11·7	1·05	22·59	68·99	7·37	14,146	0·47	Firm
" " ..	4·8	1·12	23·75	65·94	9·19	13,200	0·81	"
" " ..	3·9	1.28	24·59	66·26	7·87	13,510	0·60	"
" " ..	5·8	1·18	23·18	71·08	4·56	14,068	0·52	"
" " ..	5·6	3·07	24·07	67·34	5·52	12,890	0·59	"
" " ..	8·4	3·94	21·15	61·98	12·92	9,976	0·43	.....
North branch Wapiabi creek.	5·2	0·96	30·80	64·88	3·36	....	....	Firm
Chungo creek.	6·6	1·04	22·61	68·89	7·46	....	.. .	"

It will be seen from these analyses that the coal is very similar to that obtained in the Crowsnest field, and as is the case there, the great majority of the seams yield excellent coking coal. Mr. McEvoy constructed a small coke oven on the Bighorn to test the coking properties of the coal there, and sent five 60 pound samples from the seams on George creek to be tested in the regular ovens at Fernie. He describes the coke obtained as having a light, lustrous appearance, being of great strength, without defective or spongy parts, and giving a clear metallic ring. The low ash content shown in the analyses given is a point greatly in its favour.

DISTURBANCES IN THE COAL MEASURES.

The disturbances in the coal measures are treated under the head of economic, and not of structural geology, because of the obstacles they offer to the profitable extraction of the coal from certain portions of the basin. The greatest disturbances occur in the vicinity of the Saskatchewan valley, and are probably connected with the sudden decrease in throw of the fault by which the Bighorn range was elevated. The Kootanie formation outcrops on the anticlinal hill opposite the end of this range, but is so badly crumpled that the German Development Company has abandoned claims staked there. A series of crumples, accompanied by small faults, runs along the edge of the line of hills bordering the Saskatchewan valley on the north, and crosses the cañon of Bighorn river about 2 miles below the falls. There is reason to suppose that the strata are but little disturbed over a large portion of the flat country on the south side of the river, from the mouth of the Bighorn, to the head of the gorge through the Dakota formation. This formation forms the floor of the greater part of this flat, and it will doubtless prove profitable to sink shafts through it to the Kootanie formation below.

As has been stated, the Kootanie formation in the valley of Bighorn river is affected by a synclinal wave, which in places gives rise to dips to the northeast at angles as high as 35 degrees. Some crumples were observed about a mile above the falls, but apparently no very great thickness of the strata is affected. On Wapiabi creek there is a crumple in the Blackstone formation, and a belt about 300 feet wide in the Kootanie is disturbed near the junction of the two main branches of that creek. Mr. McEvoy estimates that a disturbed zone on George creek is from 600 to 700 feet in width, but states that the irregularity practically dies out before Blackstone creek is reached. On Chungo creek the strata dip about 60 degrees, but in spite of this high angle a very narrow belt is disturbed and only about 100 feet of the strata are affected.

GENESIS OF COAL SEAMS.

The writer is of the opinion that the shales, sandstones, and conglomerates of the Kootanie were deposited chiefly by rivers, though some of the beds contain marine fossils which indicate encroachment of the sea. Others may have been of lacustrine origin. The vegetable matter from which the seams of coal have been produced probably accumulated in peat bogs, for typical underclay with fossil roots—like that described as occurring under coal seams of Carboniferous age—is never well developed, and often the seams rest directly on coarse sandstones. The bogs may have been developed by the choking of oxbow lakes, or coastal lagoons with plant growths.

COMPANY HOLDINGS.

As has been stated, the German Development Company has purchased two concessions: one on Bighorn river, and the other extending across George and Blackstone creeks, a short distance within the Bighorn range. Other holdings have been secured on Wapiabi, Smith, and Chungo creeks. The Bighorn property, situated above the falls, could be reached by a railway skirting the hills north of the river from the end of the Bighorn range. A little cutting near the head of the cañon is probably all that would be necessary. This property probably contains the largest amount of coal which it will be possible to mine from above the entry, for, not only is the valley of the river situated near the axis of the shallow synclinal wave traversing the measures in this locality, but the hills on each side of it have not been dissected into narrow ridges by erosion, as is the case farther north. This is due to the presence here of a thick bed of sandstone and conglomerate near the top of the Kootanie, which has protected the seams under it.

The gaps through the Bighorn range which give access to the other properties are narrow, and some rocky spurs would probably have to be tunnelled before railways could be built to them. The grades would be high just outside the gaps, but beyond, the valleys appear to broaden out and probably present no engineering difficulties.

ESTIMATE OF THE AMOUNT OF WORKABLE COAL IN BIGHORN BASIN.

In making the following estimate of the amount of workable coal in the Bighorn basin a number of factors were considered. The most important of these were, of course, the aggregate thickness of the workable seams in the section, the area underlaid by the portion of the measures containing these seams, the increase in the amount of coal underlying the area owing to the dip of the strata, and the reduction of the amount of coal which it will probably be profitable to work owing to crumples and faults in the strata.

The only approximately complete sections of the measures are those measured by Mr. Dowling on a tributary of Blackstone creek, and that by Mr. McEvoy on George creek. Mr. Dowling classes as workable nine seams, with a total thickness of 64 feet 4 inches, and Mr. McEvoy eight seams, with a total thickness of 60 feet. Mr. Dowling's section was not complete, however, and several of the seams in Mr. McEvoy's were locally reduced in thickness by crumples, so that the aggregate thickness workable is probably above the figures quoted. Mr. McEvoy's section on Bighorn river is incomplete, less than 1,300 feet of strata having been examined. Seven workable seams were measured, which gave a workable thickness of 46 feet 2 inches.

These sections are all situated along the eastern edge of the basin, for, though coal was seen at several points, on the western side the strata are so badly disturbed where the exposures occur that it was impossible to measure a satisfactory section there. Consequently the estimate of the amount of coal in the deeply buried portions of the basin can only be made on the assumption that the Bighorn basin is more likely to show an increase than a decrease in the amount of coal from east to west, because an increase to the west has been found wherever sections can be compared from the same or from two or more basins in approximately the same latitude. The following are examples of this increase. In the Frank field, on the eastern edge of the mountains, the thickness of workable coal amounts to about 114 feet,[1] while at Fernie, in the third longitudinal valley, it amounts to about 172 feet.[2]

In the foothill country, south of the main line of the Canadian Pacific railway, Mr. Cairnes found that the thickness of workable coal is about 18·5 feet, while in the first longitudinal valley in the mountains, on the claims of the P. Burns Coal Company, the thickness amounted to at least 27 feet.[3] In the third longitudinal valley, just north of the Kananaskis river, Mr. McEvoy states that the thickness of workable coal amounts to 89 feet.

The most northerly point at which sections in parallel basins have been measured is in the vicinity of the Red Deer river, about 40

[1] G.S.C. Annual Report. Vol. XV. Part A, pp. 173-75.
[2] G.S.C. Annual Report Vol. XIII, Part A, 87-88.
[3] G.S.C. No. 968, pp. 9 and 9, 12.

miles south of the Bighorn basin. In the first longitudinal valley 17 feet of workable coal was all that could be found, while in the third longitudinal valley more than 90 feet were measured.[1]

These examples prove that the deeply buried portions of the Bighorn basin near its western edge are likely to contain a greater thickness of workable coal than the eastern; and, in view of the fact that over 60 feet have been found at two points on the eastern edge, and 46 feet in a partial section at another point, it is believed that a workable thickness of 60 feet was not too high a figure to use in making the estimate of the amount of coal in the entire basin.

The total area underlaid by rocks belonging to the Kootanie formation amounts to about 265 square miles, but, as the workable seams all outcrop in the upper half of the measures, it is evident that the area used in the calculations must be reduced by neglecting the area underlaid by the lower half of the measures—which are practically barren—as well as the lower half of the remaining measures, in order that the thickness of 60 feet may apply for the entire area used in the calculation. This reduction has to be made chiefly at the eastern edge of the basin, where the outcrop of the Kootanie formation is wide, and it has been thought advisable to exclude also the area underlaid by the Kootanie formation, which forms part of the western limb of the syncline. This is done because the beds in this limb have invariably been found to be badly fractured, and the coal seams crushed. These reductions leave an area of 190 square miles.

Another reduction has been made on account of the thickness to which the Kootanie formation is buried in the northwestern corner of the basin. The deepest coal mine reported is in Belgium, where the maximum depth is 3,937 feet, and several coal experts in Germany believe that coal mining to the depth of 1,500 metres (4,921 feet) or more will be profitable.[2]

The strata which overlie the Kootanie formation in certain portions of the Bighorn basin have an aggregate thickness of over 6,700 feet; but, except in the northwest corner, the uppermost and the greater thickness of the next formation occur only in detached hills, and coal could be reached beneath them from shafts not greatly ex-

[1] G.S.C. Summary Report for 1907, pp. 35-40.

[2] U. S. Geol. Survey Bulletin 424, pp. 49 and 68.

ceeding 4,000 feet in depth, though in order to reach the deepest seam shafts considerably deeper than 5,000 feet would be needed. It is quite possible that some of this coal may be too deep ever to be mined at a profit, owing to the cost of raising, and the expense necessary to overcome the great heat which may be expected at these depths—particularly in a region where great thrust faults have been developed at a comparatively recent geological date. Nevertheless, the author was of the opinion that it was better to include the coal at depths not over 6,000 feet, because improvements in mining methods will probably make it available eventually.

In the northwest corner of the basin, the Brazeau formation—uppermost in the section—underlies an extensive area, and, after allowing for the portion along the edge which could be reached from shafts less than 6,000 feet in depth, and levels 2 miles long, an area of 17 square miles remains, which must be subtracted from the area of 190 square miles obtained above. This reduction leaves the area at 173 square miles, but the dip of the strata increases the area of the underlying seams by about 8 per cent, so that the figure used in the calculation amounted to 187 square miles.

Great difficulty was also experienced in deciding the amount of coal which it will probably not be profitable to mine owing to the crumples and faults which traverse the strata. A list of the localities, where crumples were observed on the surface, has already been given, and it is extremely improbable that the deeply buried strata will be free of them—though probably they will be less numerous, for the beds are flatter, and the irregularities observed in the overlying strata are largely of the nature of gentle flexures rather than sharp folds. The writer finally reached the conclusion that in the estimate resulting from the above data as to area and thickness of the coal seams a reduction of 40 per cent should be made, in order to allow fully for the detrimental effects which these faults and crumples will have on the profitable extraction of the coal. The final data for the estimated area, therefore, is 60 per cent of the coal in an area of 187 square miles, having a thickness of 60 feet. The estimate is accordingly 6,300,000,000 long tons.

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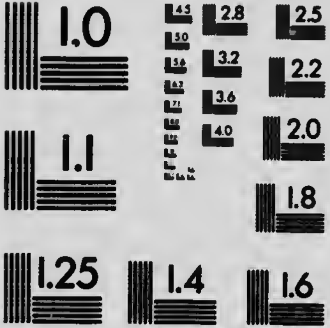

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CANADA
DEPARTMENT OF MINES
GEOLOGICAL SURVEY BRANCH

HON. W. TEMPLEMAN, MINISTER; A. P. LOW, DEPUTY MINISTER;
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(SINCE 1885)
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941. Preliminary Geological Map of Rossland and vicinity, scale 1,600 ft. = 1
987. Princeton coal basin and Copper Mountain Mining camp, scale 40 ch. = 1 in.
989. Telkwa river and vicinity, scale 2 m. = 1 in.
997. Nanaimo and New Westminster Mining division, scale 4 m. = 1 in.
1001. Special Map of Rossland. Topographical sheet. Scale 400 ft. = 1 in.
1002. Special Map of Rossland. Geological sheet. Scale 400 ft. = 1 in.
1003. Rossland Mining camp. Topographical sheet. Scale 1,200 ft. = 1 in.
1004. Rossland Mining camp. Geological sheet. Scale 1,200 ft. = 1 in.
1068. Sheep Creek Mining camp. Geological sheet. Scale 1 m. = 1 in.
1074. Sheep Creek Mining camp. Topographical sheet. Scale 1 m. = 1 in.
1095. 1A. Hedley Mining district. Topographical sheet. Scale 1,000 ft. = 1 in.
1096. 2A. Hedley Mining district. Geological sheet. Scale 1,000 ft. = 1 in.
1105. 1A. Golden Zone Mining camp. Scale 600 ft. = 1 in.
1106. 3A. Mineral Claims on Henry creek. Scale 800 ft. = 1 in.
1125. Hedley Mining district. Structure Sections. Scale 1,000 ft. = 1 in.
Deadwood Mining camp. Scale 400 ft. = 1 in. (Advance sheet.)

ALBERTA.

591-596. Peace and Athabaska rivers, scale 10 m. = 1 in.
*808. Blairmore-Frank coal-fields, scale 180 ch. = 1 in.
892. Costigan coal basin, scale 40 ch. = 1 in.
929-936. Cascade coal basin. Scale 1 m. = 1 in.
963-966. Moose Mountain region. Coal Areas. Scale 2 m. = 1 in.
1010. Alberta, Saskatchewan, and Manitoba. Coal Areas. Scale 35 m. = 1 in.
1117. 5A.—Edmonton. (Topography). Scale ½ m. = 1 in.
1118. 6A.—Edmonton. (Clover Bar Coal Seam). Scale ½ m. = 1 in.
1132. 7A.—Bighorn coal-field. Scale 2 m. = 1 in.

SASKATCHEWAN.

1010. Alberta, Saskatchewan, and Manitoba. Coal Areas. Scale 35 m. = 1 in.

MANITOBA.

804. Part of Turtle mountain showing coal areas. Scal[illegible] 1½ m. = 1 in.
1010. Alberta, Saskatchewan, and Manitoba. Coal [illegible] [illegible]le 35 m. = 1 in.

NORTH WEST TERRITO[illegible]

1089. Explored routes on Albany, Severn, and Wini[illegible] [illegible]le 8 m. = 1 in.
1099. Pelly, Ross, and Gravel rivers, Yukon and No[illegible] [illegible]erritorie[illegible] Scale 8 m. = 1 in.

ONTARIO.

227. Lake of the Woods sheet, scale 2 m. = 1 in.
*283. Rainy Lake sheet, scale 4 m. = 1 in.
*312. Hunter Island sheet, scale 4 m. = 1 in.
343. Sudbury sheet, scale 4 m. = 1 in.
*373. Rainy River sheet, scale 2 m. = 1 in.
560. Seine River sheet, scale 4 m. = 1 in.
570. French River sheet, scale 4 m. = 1 in.

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*Publications marked thus are out of print.

*580. Lake Shebandowan sheet, scale 4 m. = 1 in.
599. Timiskaming sheet, scale 4 m. = 1 in. (New Edition 1907).
605. Manitoulin Island sheet, scale 4 m. = 1 in.
606. Nipissing sheet, scale 4 m. = 1 in. (New Edition 1907).
660. Pembroke sheet, scale 4 m. = 1 in.
663. Ignace sheet, scale 4 m. = 1 in.
708. Haliburton sheet, scale 4 m. = 1 in.
720. Manitou Lake sheet, scale 4 m. = 1 in.
*750. Grenville sheet, scale 4 m. = 1 in.
770. Bancroft sheet, scale 2 m. = 1 in.
775. Sudbury district, Victoria mines, scale 1 m. = 1 in.
*780. Perth sheet, scale 4 m. = 1 in.
820. Sudbury district, Sudbury, scale 1 m. = 1 in.
824–825. Sudbury district, Copper Cliff mines, scale 400 ft. = 1 in.
852. Northeast Arm of Vermilion iron ranges, Timagami, scale 40 ch. = 1 in.
864. Sudbury district, Elsie and Murray mines, scale 400 ft. = 1 in.
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914. Preliminary Map of Timagami and Rabbit lakes, scale 1 m. = 1 in.
951. Geological Map of parts of Algoma and Thunder bay, scale 8 m. = 1 in.
1023. Corundum Bearing Rocks. Central Ontario. Scale 17½ m. = 1 in.
1076. Gowganda Mining Division, scale 1 m. = 1 in.
1080. Lake Nipigon, Thunder Bay district, Ont. Scale 4 m. = 1 in.

QUEBEC.

*251. Sherbrooke sheet, Eastern Townships Map, scale 4 m. = 1 in.
287. Thetford and Coleraine Asbestos district, scale 40 ch. = 1 in.
375. Quebec sheet, Eastern Townships Map, scale 4 m. = 1 in.
*571. Montreal sheet, Eastern Townships sheet, scale 4 m. = 1 in.
*665. Three Rivers sheet, Eastern Townships Map, scale 4 m. = 1 in.
667. Gold Areas in southeastern part, scale 8 m. = 1 in.
*668. Graphite district in Labelle county, scale 40 ch. = 1 in.
918. Chibougamau region, scale 4 m. = 1 in.
976. The Older Copper-bearing Rocks of the Eastern Townships, scale 8 m. = 1 in.
1007. Lake Timiskaming region, scale 2 m. = 1 in.
1029. Lake Megantic and vicinity, scale 2 m. = 1 in.
1066. Lake Timiskaming region. Scale 1 m. = 1 in.

NEW BRUNSWICK.

*675. Map of Principal Mineral Occurrences. Scale 10 m. = 1 in.
969. Map of Principal Mineral Localities. Scale 16 m. = 1 in.

NOVA SCOTIA.

*812. Preliminary Map of Springhill coal-field, scale 50 ch. = 1 in.
833. Pictou coal-field, scale 25 ch. = 1 in.
897. Preliminary Geological Plan of Nictaux and Torbrook Iron district, scale 25 ch. = 1 in.
927. General Map of Province showing gold districts, scale 12 m. = 1 in.
937. Leipsigate Gold district, scale 500 ft. = 1 in.
945. Harrigan Gold district, scale 400 ft. = 1 in.
995. Malaga Gold district, scale 250 ft. = 1 in.
1012. Brookfield Gold district, scale 250 ft. = 1 in.
1019. Halifax Geological sheet. No. 68. Scale 1 m. = 1 in.
1025. Waverley Geological sheet. No. 67. Scale 1 m. = 1 in.
1030. St. Margaret Bay Geological sheet. No. 71. Scale 1 m. = 1 in.
1037. Windsor Geological sheet. No. 73. Scale 1 m. = 1 in.
1043. Aspotogan Geological sheet. No. 70. Scale 1 m. = 1 in.

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Reports and Maps may be ordered by the numbers prefixed to titles.

Applications should be addressed to The Director, Geological Survey, Department of Mines, Ottawa.

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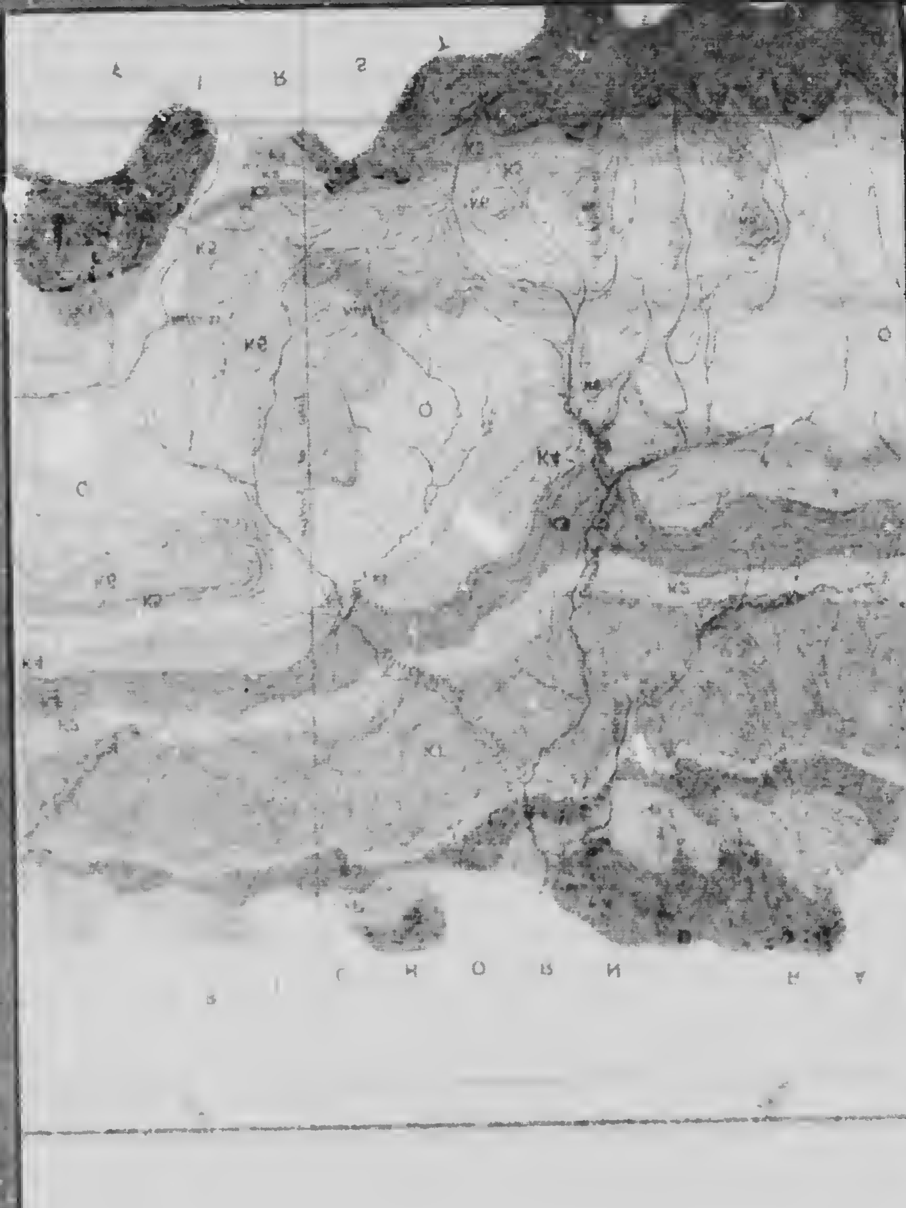
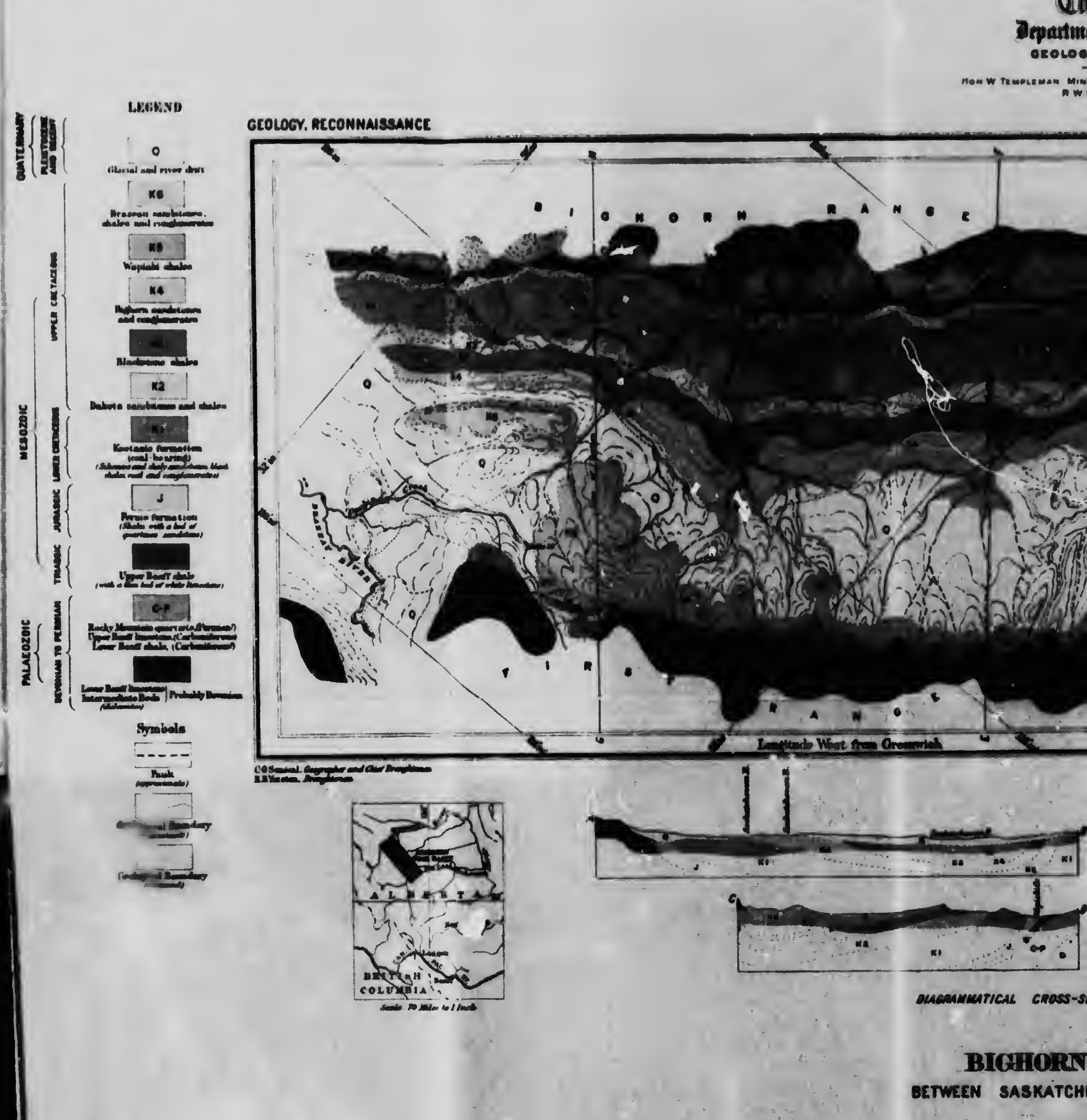
*Publications marked thus are out of print.



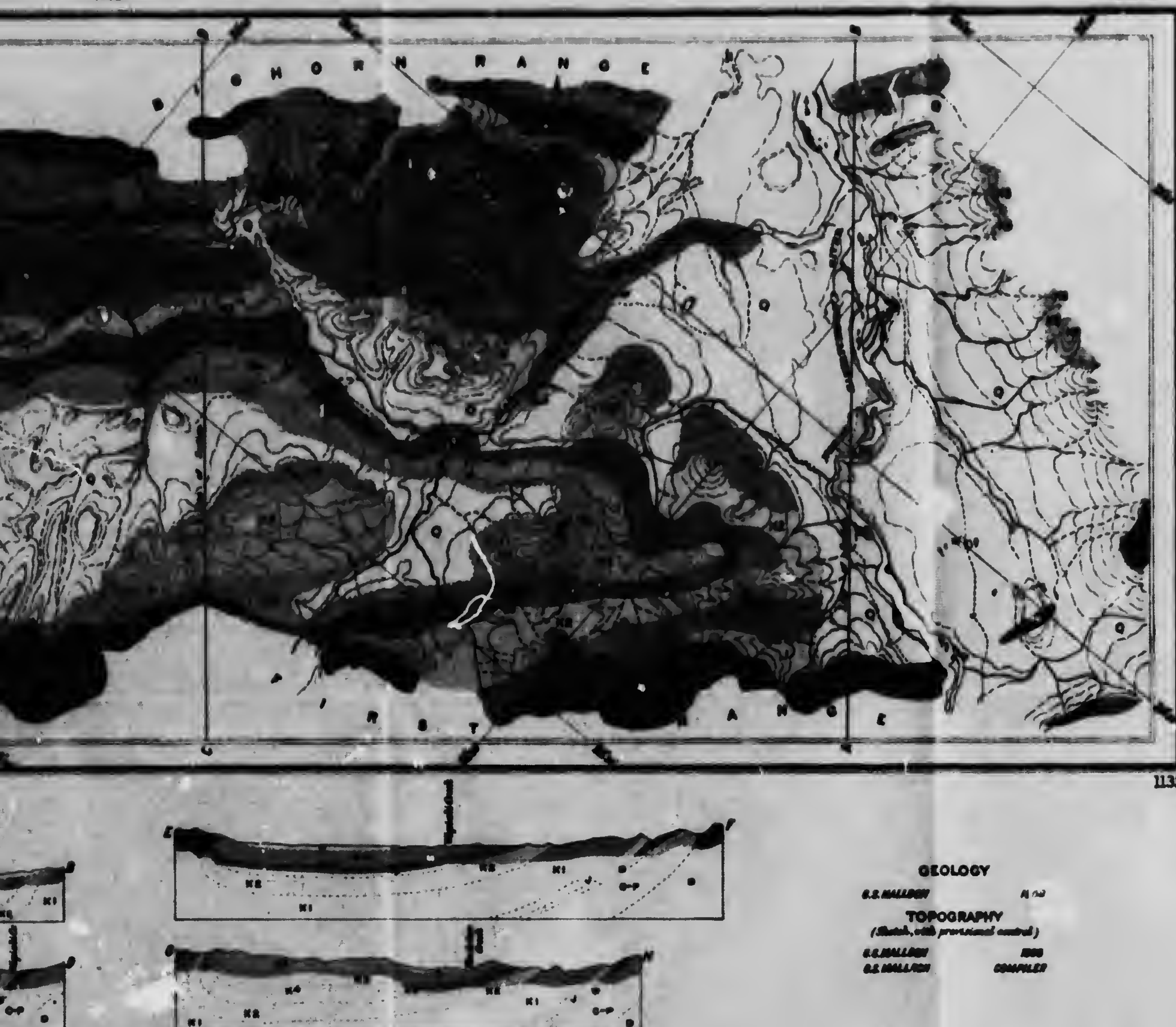


LEGEND
GEOLOGY, RECONNAISSANCE
QUATERNARY
PLEISTOCENE AND RECENT
Q
Glacial and river drift
K6
Brazeau sandstones, shales and conglomerates
K5
Wapiabi shales
K4
Bighorn sandstones and conglomerates
Blackstone shales
K2
Dakota sandstones and shales
Kootanie formation (coal-bearing)
J
Fernie formation
Upper Banff shale
C-P
Rocky Mountain quartzite (Permian?)
Upper Banff limestone (Carboniferous)
Lower Banff shale (Carboniferous?)
Lower Banff limestone
Intermediate Beds
Probably Devonian
UPPER CRETACEOUS
MESOZOIC
JURASSIC
TRIASSIC
PALAEOZOIC
DEVONIAN TO PERMIAN
Symbols
Fault (approximate)
B I G H O R N R A N G E
F I R S T
R A N G E
Longitude West from Greenwich
ALBERTA
BRITISH COLUMBIA
Scale 70 Miles to 1 Inch
DIAGRAMMATICAL
BIGHORN
BETWEEN SASKATCH

Canada
Department of Mines
GEOLOGICAL SURVEY

…LEMAN MINISTER, A P LOW DEPUTY MINISTER
R W BROCK, DIRECTOR

1910



LEGEND

Culture

Trails

Water

Rivers and Streams (mapped at high water mark)

Watercourses with intermittent flow

Relief

Sketched land forms

Magnetic declination about 27° East

GEOLOGY

D.S. MALLOCH 1910

TOPOGRAPHY

(Sketch, with provisional control)

D.S. MALLOCH 1910

D.S. MALLOCH COMPILER

MAP 7A

…HORN COAL BASIN

…SKATCHEWAN AND BRAZEAU RIVERS

ALBERTA

Scale: 1/126,720

Miles

Kilometres

2 MILES TO 1 INCH

To accompany Memoir No.9